Volume 19 Number 9

BULLETIN
of the
AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

SEPTEMBER, 1935

LATE PALEOZOIC CRUSTAL MOVEMENTS OF EUROPE AND NORTH AMERICA[1]

RAYMOND C. MOORE[2]
Lawrence, Kansas

ABSTRACT

Recent compilations of data concerning orogenic and epirogenic movements of the earth's crust, especially by Stille and Bucher, strongly support the conclusion that both of these types of crustal deformation are markedly periodic and that they are related. Times of essential stability of the crust during which sedimentation proceeds uninterruptedly in many regions alternate with times of crustal unrest in which orogenic movements may contemporaneously affect certain widely separated geosynclinal belts but fail to affect others. The chief marine transgressions of continents occur during epochs of general crustal stability. The making of widespread disconformities in areas not affected by orogenic movements appears to coincide in time with the occurrence of orogenic disturbances in geosynclines.

Stille recognizes six epochs of more or less well defined orogenic disturbance and accompanying crustal unrest in the post-Devonian part of the Paleozoic era. These are (1) Bretonian, post-Devonian pre-Dinantian, (2) Sudetian, post-Dinantian pre-Namurian, (3) Erzgebirgian, mid-Namurian, (4) Asturian, post-Westphalian pre-Stephanian, (5) Saalian, post-Early Rotliegende pre-Late Rotliegende, and (6) Pfälzian, post-Permian pre-Triassic. Excepting numbers 1 and 6, however, the indicated disturbances do not coincide with period boundaries as now commonly defined.

The present paper reviews evidences primarily from North American areas bearing on the age of Late Paleozoic crustal movements and compares this record with that of Europe. At least nine series that are separable on the basis of structural and paleontologic criteria appear to be recognizable in the post-Devonian section of North America. The breaks between these stratigraphic series or "blocks" represent orogenic or epirogenic movements. In general, it appears that times of orogenic movement in Europe are matched by epirogenic movements in North America and conversely that orogeny in America may be represented by epirogeny in Europe.

Multitudinous problems as to the nature of deformative movements of the earth's crust, their causes and effects, and their distribu-

[1] Manuscript received, June 8, 1935.

[2] University of Kansas.

tion in time and space, have long engaged the attention of geologists. Many of these problems have very important theoretical and practical bearing on considerations in petroleum geology, and likewise on such seemingly distant fields as stratigraphy and paleontology. It is beyond the scope of this paper, however, even to summarize these relationships, a majority of which are adequately treated in recent works by Stille (37), Bucher (8), and others, where one may find detailed critical discussion.

The purpose of the writer will be served by offering first a few brief, somewhat categorical introductory statements concerning the periodicity of diastrophism and the relation of orogenic to epirogenic movements, and then by reviewing, as concisely as possible, known facts as to the nature and geologic date of Late Paleozoic earth movements in various parts of Europe and North America. Because of limitations of present knowledge, such a review necessarily includes some tentative statements, particularly as regards correlation of certain stratigraphic units and determination of the precise date of certain crustal deformations.

The writer advances the thesis that in the post-Devonian part of Late Paleozoic history there is widespread evidence of at least nine distinct epochs of diastrophic movement that can be differentiated from intervening times of relative crustal quiet, and that recognition of this diastrophic periodicity furnishes basis not only for more significant stratigraphic classification and more exact correlation of stratigraphic units in different parts of this continent, but also that it may provide foundation for more exact comparison of the Late Paleozoic record in different continental areas. This thesis invites critical testing from future closer scrutiny of the field evidences.

Periodicity of diastrophism.—Consideration of known geologic history in almost any region of the earth leads to the conclusion that crustal deformations have been neither continuous in time nor of uniform nature. Certain belts which are characterized by unusual thickness of sedimentary accumulations record the occurrence of one or more epochs of orogenic diastrophism in which, with varying intensity, the rocks have been folded, faulted, metamorphosed, and injected by igneous rocks. These belts of crustal mobility are the geosynclines. Other areas only record the occurrence of intermittent sinking, elevation, or gentle warping, which are defined by the successive sheets of subparallel stratigraphic units separated at intervals by disconformities. These are the so-called foreland tracts that comprise the relatively immobile stable platform areas of the continents. In addition, there are districts that from time to time appear to have been

elevated more or less strongly, so that erosion has carried from them great quantities of rock materials to adjacent regions of sedimentation. These are the geanticlinal regions.

That subsidence in geosynclinal and foreland areas has been interrupted periodically by relative movements in the opposite direction is abundantly shown by occurrence of stratigraphic hiatuses, accompanied in some instances by physical evidence of erosion. That uplift of geanticlines, likewise, has been intermittent in amount and in time is as clearly shown by the thickness and coarseness of the clastic sediments of different age derived from them. The geologic date of orogenic movements is determinable within varyingly precise limits by discovery of the age of the youngest strata affected by the movements and of the next succeeding beds not affected by this diastrophism. These generalizations are so self-evident and generally recognized that they do not call for further comment. The evidence appears very definitely to indicate that the movements are not continuous in time but are periodic. Some of them coincide with the present defined boundaries between geologic periods or series, but it is evident that some do not. Whether this partial disagreement between geochronologic classification and the record of the time of diastrophic movements is a fault of our classification or whether it is due to a lack of contemporaneity of diastrophic movements in different regions is a subject for consideration in this paper.

Relation of orogenic and epirogenic diastrophism.—An extended survey of geologic evidences from all parts of the world, such as that presented by Stille, strongly supports the conclusion that times of orogenic activity in geosynclinal belts coincide with *relative* uplift of lands and withdrawal of seas in regions subject only to epirogenic movements. Strong folding movements in a geosyncline may die out in a surprisingly short distance horizontally away from the source of pressure, but there seem to be few places on the continents where sedimentation was continuous during the time of an orogenic movement. It is true, as well shown in the Late Paleozoic deposits of the Mid-Continent region of the United States, that disconformities in the flat-lying formations may be obscure, even at the borders of areas subjected to mountain-making uplift, but these disconformities are present and they are important planes of stratigraphic partition. We may agree with Bucher (8, p. 439) that wherever it is possible to determine closely the geologic date of a mountain-making movement we may expect to find a widespread hiatus in the essentially flat-lying sediments of the stable platform area. This means, as held by T. C. Chamberlin (10), that diastrophism does have fundamental value in

stratigraphic classification and geochronology. It seems preferable to believe that the apparent lack of agreement which exists in many cases between the time of certain important diastrophic movements and the major boundaries of our geologic time scale is due rather to erroneous and artificial features of the latter and to incompleteness of our knowledge than to failure of the principle.

It appears possible—indeed, it is very probable—that the widespread withdrawal of epicontinental seas and the interruption of sedimentation that is indicated by disconformities within the stable platform areas of the continents, do not signify upward movement of these parts of the crust. Subequal elevation of enormous crustal segments is much more difficult to conceive as an actual epirogenic movement than as a result of depression of mean sea-level. If uplift of mountains in some geosynclinal belt is accompanied by crustal changes that for a time somewhat increase the capacity of oceanic basins, it is easy to understand that lowered sea-level should result in simultaneous withdrawal of shallow seas from different continental platforms. Since the temporary elevation of the platform areas may be only relative, rather than due to actual movement of continental masses, it is perhaps improper to speak of epirogenic movement, but because the net results are essentially the same and because we do not have another concise means of expressing the inferred conditions, we shall designate as epirogenic any widespread *relative* movement of sea-level.

It is very pertinent to observe that orogenic movements in geosynclinal belts appear not to have affected all of these relatively weak tracts of the earth's crust equally or simultaneously. Certain Paleozoic folding movements are strongly marked in some belts and not at all in others even closely adjacent to them, or a movement that is clearly evident in one area may be weakly expressed in another. The post-Silurian Caledonian orogeny profoundly disturbed northwestern Europe but failed to affect the Appalachian trough. Similarly, the time of important folding movements in Europe or in other continents may not coincide with the chief epochs of orogeny in North America. The different orogenic movements of Carboniferous time quite differently affected closely adjoining areas in western Europe.

Reviewing the evidences as to Late Paleozoic diastrophism, it appears that the geanticlinal tracts were generally the first to feel effects of compressive movements. Uplifts of these areas provided great quantities of clastic sediments to adjacent geosynclinal regions. Subsequent movement re-elevated the geanticlines and deformed at least part of the geosynclines. Still later folding strongly affected pre-

viously unfolded parts of geosynclinal belts. Such successive orogenic phases or pulsations are clearly indicated, for example, in parts of Europe, western Texas, and southern Oklahoma.

LATE PALEOZOIC CRUSTAL MOVEMENTS IN EUROPE

Partly because Europe is the classic region where stratigraphic and structural units of the Late Paleozoic rocks were first clearly defined, and partly because important studies have recently been made in European areas, it is desirable to summarize first the evidences of Late Paleozoic diastrophism reported in this continent. Under the terms Variscan, or Hercynian, older writers have collectively grouped mountain-building movements in Carboniferous and Permian times that formed the widespread "Paleozoic Alps" of western Europe. It has long been recognized that the folding movements were definitely earlier in some regions than in others, but we are primarily indebted to Stille for compilation of data that serve to differentiate the successive movements and to indicate the areas chiefly affected by each of them. The following summary is chiefly drawn from Stille, but extensive additional European literature has also been consulted.

As shown in the accompanying table, six phases of Late Paleozoic or Variscan folding are recognized in Europe. These orogenies correspond to mountain-building movements that R. T. Chamberlin (9) called Devonides (Bretonian), Culmides (Sudetian), Westphalo-Carbonides (Asturian), and Permo-Carbonides (Saalian, Pfälzian).

LATE PALEOZOIC OROGENIC MOVEMENTS IN EUROPE
(After Stille)

TRIASSIC
- *Pfälzian orogeny* (weak)

PERMIAN
- Upper Permian
  - Zechstein, Thuringian
- Lower Permian
  - Upper Rotliegende, Saxonian
  - *Saalian orogeny* (rather weak)
  - Lower Rotliegende, Autunian

CARBONIFEROUS
- Upper Carboniferous
  - Ottweiler, Stephanian, Uralian
  - *Asturian orogeny* (strong)
  - Saarbrücker, Westphalian, Moscovian
  - Flözleeres, Upper Namurian
  - *Erzgebirgian orogeny* (local)
  - Waldenburger, Lower Namurian
  - *Sudetian orogeny* (strong)
- Lower Carboniferous (Dinantian)
  - Viséan
  - Tournaisian
  - Etroeungtian
  - *Bretonian orogeny* (strong)

DEVONIAN

Bretonian diastrophism.—The Bretonian orogeny, named from Brittany in northwestern France, is clearly evidenced in the Laval syncline (Bassin du Maine) where steeply folded Devonian rocks of great thickness are unconformably overlain by Lower Carboniferous (Dinantian) strata with a basal conglomerate containing Devonian pebbles. In the Ancenis basin, a little farther south, the basal Lower Carboniferous rests in most places on folded Silurian rocks, but locally the Devonian is present. The Lower Carboniferous in southern Belgium and north of the Rhenish Schiefergebirge in northwestern Ger-

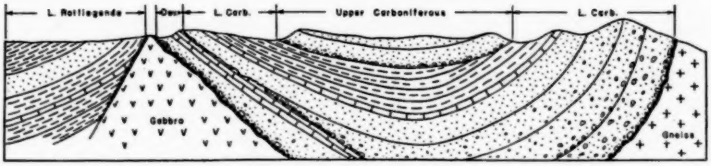


FIG. 1.—Diagrammatic section of Lower Silesian coal basin showing (1) unconformity and overlap at base of coarse clastic Lower Carboniferous beds, indicating Bretonian orogeny, and (2) slight unconformity at base of Upper Carboniferous, indicating Sudetian orogeny. (After Kayser.)

many is mostly concordant with Upper Devonian rocks, but the occurrence of a hiatus indicates a disconformity. Locally, the Devonian is nearly vertical, overlain unconformably by Lower Carboniferous. East of the Schiefergebirge, folded and bevelled Devonian rocks are overlain by upper Lower Carboniferous (Culm). Culm beds belonging to the upper part of the Lower Carboniferous overlap various divisions of the Devonian and Silurian in the Harz Mountain region. There is evidence of important faulting in southern Scotland between the time of deposition of upper Old Red sandstone and deposition of early Lower Carboniferous strata, but in most other parts of Europe, notably in Spain and Portugal, the Lower Carboniferous appears concordant on the Devonian.

Sudetian diastrophism.—The Sudetian orogeny, named from the Sudetes in Lower Silesia, southeastern Germany, approximately defines the boundary between Lower and Upper Carboniferous as these terms are applied in most parts of Europe. That is to say, although the European Lower and Upper Carboniferous are separated in many places by a strong angular unconformity, the boundary is not thus defined in others. Where the latter condition prevails, as in parts of England, northern France, Belgium, Holland, the lower Rhineland and in Russia, the line of division between so-called uppermost Dinantian (Lower Carboniferous) and overlying beds classed as

Namurian (basal Upper Carboniferous) has been selected on the basis of first appearance of a genus of goniatites known as *Eumorphoceras*. This definition has gained wide acceptance because of an agreement made by the Congrès de Stratigraphie Carbonifère, an international gathering of European geologists at Heerlen, Holland, in 1927. Certain physical as well as paleontologic evidences suggest that the selected boundary between Dinantian and Namurian may not be the most significant horizon of stratigraphic partition, and accordingly there is now some dissenting opinion (17) as to the proper position of this boundary in the most nearly complete sections. Further reference will be made to this point in comparing the European and American sections.

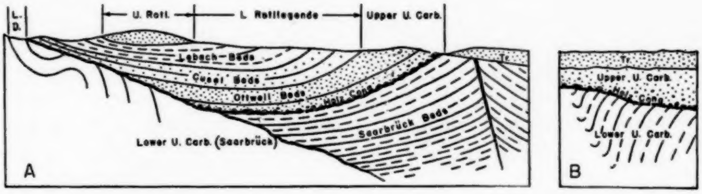


FIG. 2.—A. Diagrammatic section across part of Saar Basin, western Germany, showing overlap of Upper Carboniferous and Permian beds on Lower Carboniferous (Sudetian orogeny). The Stephanian beds (Ottweil and Holz) are disconformable on Westphalian (Saarbrück beds). (After Kayser from Nasse.) B. Section showing angular unconformity (Asturian orogeny) between Stephanian (Holz conglomerate) and Westphalian (lower Upper Carboniferous or Saarbrück) observed in La Houvre mine, southwestern Saar region. (Reported by Stille.)

The Sudetian folding is weakly expressed in the Sudetes, but elsewhere in Germany and some other parts of western Europe it is the most important of the Late Paleozoic orogenies. In Saxony the Viséan (upper Dinantian) and lower divisions of the Lower Carboniferous are strongly folded and overlain unconformably by the coal-bearing Hainichen beds, which have been classed by some writers as basal Upper Carboniferous and by others as Culm, or uppermost Lower Carboniferous. The Hainichen beds are now correlated with the Waldenburg and Ostrau deposits of Silesia, all being classed as basal Namurian. Elsewhere in southern and southeastern Germany younger beds of the Upper Carboniferous or strata belonging to the still higher Rotliegende, which is classed as Lower Permian, rest on folded and in places metamorphosed upper Lower Carboniferous (Culm).

Along the north front of the Rhenish Schiefergebirge in the lower Rhine, Westphalia, near Aachen, and in Belgium, the Namurian beds rest concordantly, although in places apparently with some hiatus,

on upper Lower Carboniferous Viséan limestones, but on the south side of the Schiefergebirge, slightly folded Saarbrücker beds, of Westphalian (middle Upper Carboniferous) age, rest unconformably on strongly folded Devonian or older Paleozoic rocks. The Saarbrücker beds are next younger than the Namurian. In the Schwarzwald region of southwestern Germany, folded Culm (upper Lower Carboniferous) is unconformably overlain by "upper Culm" which is now regarded as basal Namurian in age. The observed relations thus correspond closely to conditions in Saxony.

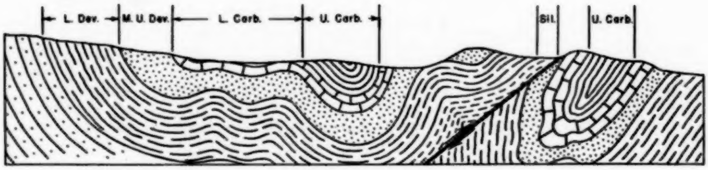


FIG. 3.—Diagrammatic section of Paleozoic rocks in geosynclinal belt north of Ardennes and Rhenish Schiefergebirge. Folding represents Asturian orogeny. (After Kayser.)

In various parts of England and southern Scotland the Millstone grit of Namurian age rests unconformably on different divisions of the Lower Carboniferous. The Millstone grit records a very pronounced uplift of a geanticlinal area lying on the northwest, but except locally, the structure of the Lower and Upper Carboniferous is concordant. The Pennine district and adjacent parts of northern England is a most important area from the standpoint of studies of the boundary between Lower and Upper Carboniferous, for lithologic and stratigraphic differentiation of the rock succession is well shown and much detailed paleontological work has been done here. This work began with John Phillips' classic works on the "Geology of Yorkshire" and "Petrifacta derbiensis" that appeared a century ago, and includes especially recent studies by E. J. Garwood (13–15) and delineation of goniatite zones by W. G. Bisat (5). The boundary at the base of the beds classed as Millstone grit by the Geological Survey of Great Britain has been placed lower and lower in late years until now a considerable thickness of strata included in the Yoredale and Pendleside series (42), formerly classed as Lower Carboniferous, is regarded as belonging to the Upper Carboniferous. Attention will be directed again to the Millstone grit problem in comparing the European and American geologic records.

In parts of Spain and southern Portugal beds classed as Upper

Carboniferous rest conformably on Lower Carboniferous, continuity of goniatite-bearing beds apparently indicating lack of any hiatus.

At many other places in western Europe Lower Carboniferous strata are strongly folded, but the next overlying beds belong to the Upper Carboniferous (Stephanian) or to the so-called Lower Permian (Rotliegende). These places probably, but not certainly, indicate Sudetian folding.

Erzgebirgian diastrophism.—In parts of Germany, notably the Erzgebirge and portions of Silesia, there is distinct discordance between lower Namurian beds (Waldenburger and Ostrauer beds, or Rand group) and the next succeeding deposits (Weissteiner beds, Sattelflöz group) that are classed as upper Namurian. The lower Namurian may be overlain unconformably also by Westphalian or younger Carboniferous or by Rotliegende beds. The deformation thus indicated has been called the Erzgebirgian orogeny. Although evidence of folding of this date is lacking in most other parts of Europe, there is such widespread indication from lithologic and paleontologic characters of a break within the Namurian that there is a growing tendency to recognize the existence and importance of Erzgebirgian diastrophism.

In the region of Westphalia, Belgium, and northern France, where the Namurian division of the Upper Carboniferous has its type development, the lower Namurian (Hangende Alaunschiefer, Assise de Chokier), consisting mainly of dark-colored shales, is separable from the upper Namurian (Flözleeres and Magerkohle, Assise d'Andenne and de Châtelet) by the occurrence of prominent sandstones and locally of conglomerates in the lower part of the upper Namurian, and by a marked "break" in the character of the fossil floras (16). The change in the character of the sediments and the occurrence of this "paleontological break" correspond to the Erzgebirgian diastrophism.

Similar conditions are observed in England and Scotland. In the Yorkshire region this break appears to fall near the base of the prominent Kinderscout grit, a subdivision of the Millstone grit. This is at or somewhat below the base of the *Reticuloceras* zone and in the *Homoceras* zone as defined by goniatite horizons. In Lanarkshire, Scotland, upper Millstone grit of post-Erzgebirgian age rests unconformably on beds that belong near the base of the Lower Carboniferous. Elsewhere in Scotland, studies, mainly by Kidston on plants and by Traquair on fishes, have established the existence of a prominent paleontologic break within the lower half of beds classed as Millstone grit, and in Scotland this break has been reckoned as the boundary between Lower and Upper Carboniferous (22, 32). Thus it

appears that deposits of the same age are classed as upper Lower Carboniferous in Scotland and as lower Upper Carboniferous in England. The break in the Millstone grit sequence is believed to correspond to the Erzgebirgian deformation.

Asturian diastrophism.—The Asturian orogeny is named from Asturia in northwestern Spain, where upper Upper Carboniferous (Stephanian) rests unconformably on folded lower Upper Carboniferous (Westphalian) and older rocks. Similar relations are observed elsewhere in Spain and Portugal. In the Ancenis basin of northwestern France, the only French syncline that contains representatives of all four divisions of the Carboniferous (Dinantian, Namurian, Westphalian, Stephanian), the Stephanian rests unconformably on Westphalian.

The Schwarzwald area in southwestern Germany contains no basins with both Westphalian and Stephanian together, but in the same belt of folding the Westphalian is very strongly deformed while the Stephanian is only gently folded.

The lower Upper Carboniferous (Namurian and Westphalian) of Westphalia, Rhineland, Belgium, and northern France is very strongly folded and thrust-faulted, but Stephanian beds are absent. Locally there is a conglomerate (Menden), identified as youngest Carboniferous or oldest Rotliegende, that unconformably overlies truncated folds of the Westphalian strata. This conglomerate was faulted and bevelled by erosion before deposition of Permian (Zechstein) strata which cover much of the region.

South of the Schiefergebirge, in the Saar Basin, Saarbrücker (Westphalian) and Ottweiler (Stephanian) beds show conformable structure in most places, but at the contact there is a prominent conglomerate (Holz) which locally is observed to rest with sharp angular unconformity on underlying strata (Fig. 2).

In southern and southeastern Germany (Saxony and the Sudetes, Bohemia) beds of Stephanian age rest with angular unconformity on Westphalian rocks.

An important disconformity is reported in parts of central England between the Middle and Upper Coal Measures, but the latter, according to the present view, is not younger than uppermost Westphalian.

According to recent studies (4), it appears that in some of the Carboniferous basins of the Central Plateau of France, the oldest Carboniferous deposits are not Stephanian, as is the case generally, but upper Westphalian. These Westphalian beds rest with strong unconformity on much deformed pre-Carboniferous rocks and are

succeeded concordantly by basal Stephanian sediments, which, however, commonly contain prominent sandstones and conglomerates. Entirely similar conditions are described in the Sudetic Mountains of southeastern Germany and Bohemia (40). This is inferred to signify a pre-Asturian earth movement, or, with broadening of definition,

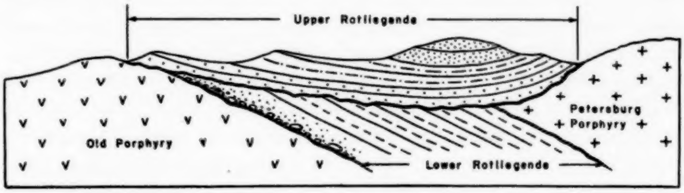


FIG. 4.—Diagrammatic section in vicinity of Halle, Germany, showing evidences of Saalian orogeny. (After Kayser.)

the Asturian diastrophism may be considered to include this pre-Stephanian movement as an initial "phase." Although the upper Westphalian beds of the lower Rhine region lie parallel on the middle and lower beds, there is some indication of possible lithologic and paleontologic differentiation of the part that corresponds to the unconformably overlapping late Westphalian deposits in other regions.

Saalian diastrophism.—Throughout central Europe beds classed as lower Rotliegende and included in the Permian rest with parallel

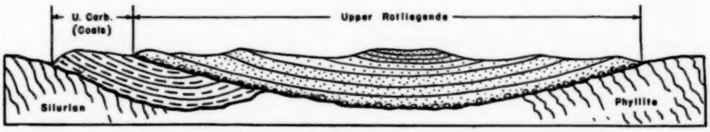


FIG. 5.—Diagrammatic section of Chemnitz Basin in Erzgebirge region, Germany, showing evidence of Saalian orogeny. (After Kayser.)

structure and apparent conformity on Upper Carboniferous strata. Nowhere does there appear to be evidence of warping or folding movements at the position of this boundary, which somewhat arbitrarily has come to be defined as the horizon where the fern *Callipteris conferta* first makes its appearance. In Europe, as in North America, there has been much difficulty and disagreement, therefore, in location of this boundary.

The Saalian orogeny separates the Saxonian or "Middle Permian" (upper Rotliegende) from the Autunian or "Lower Permian" (lower Rotliegende) beds. It appears to have been much weaker than the

Asturian and Sudetian folding in various parts of western Europe. At many places in Germany and elsewhere in western Europe the younger Permian rests unconformably on the older Permian or on Carboniferous rocks, and as may be expected also, the post-Saalian beds overlap onto older Paleozoic or pre-Paleozoic rocks. The unconformity at the base of post-Saalian Permian rocks is strikingly shown in Great Britain. In places there are thick accumulations of coarse conglomerate and breccia at the base of these Permian beds.

According to Stille (37, p. 83), the Artinsk beds of eastern Russia are believed to be older than the time of Saalian folding, but paleontologic and some structural evidences indicate, on the other hand, that the thick sandstones and conglomerates which form the lower Artinsk deposits are probably younger than the time of Saalian deformation. In the Donetz Basin of southern Russia, Stille notes that moderately folded Upper Carboniferous (Uralian) and older beds are unconformably overlain by the salt-bearing Bachmut strata of Upper Permian age.

LATE PALEOZOIC CRUSTAL MOVEMENTS IN NORTH AMERICA

The record of Late Paleozoic orogenic and epirogenic earth movements in North America is probably not less complete or definite that that of Europe. There are noteworthy differences, however, and these are of such nature that the evidences of the one continent seem likely to supplement those of the other and to make geologic conditions in each more clearly understandable. The writer will first undertake to summarize knowledge of Late Paleozoic diastrophism in North America, making little or no reference in this part of the paper to conditions in Europe, and then attention will be given to comparison and correlation of the European and American earth movements.

Some of the epochs of crustal unrest during the Late Paleozoic history of North America witnessed pronounced mountain-building deformations in certain places, and appropriate names, such as Marathon disturbance and Appalachian revolution, have been given to these orogenies. Although the disturbances of this sort are accompanied by development of unconformities, not only in geosynclines but in large parts of the neighboring stable platform areas of the continent, the name of the disturbance is rarely if ever applied to the unconformity or to the epirogenic movement (possibly consisting only of depression of sea-level rather than elevation of the land) that is related to the disturbance in time and doubtless in origin. There are a number of widespread unconformities, forming important

planes of stratigraphic separation that, so far as known, are not associated with orogenic deformations involving any part of North America. These "breaks" are not designated by geographic names. Accordingly, it seems best to indicate the crustal movements that are to be discussed by reference to a widely recognized stratigraphic unit that belongs to time immediately following the movement. Thus we may speak of pre-Kinderhook or pre-Pottsville orogenic or epirogenic movements, with the understanding that it is the diastrophism just preceding deposition of these units to which allusion is made. This usage may carry the implication, objectionable to some, that the crustal movement is confined entirely to time preceding the earliest of the named succeeding beds, but such difficulty seems unimportant both theoretically and practically.

The accompanying tabulation shows the stratigraphic position of the more important breaks in the Late Paleozoic succession of North America and indicates the inferred epochs of orogenic movements that are recorded in various geosynclinal areas.

TABLE I

DISTRIBUTION OF IMPORTANT BREAKS AND ASSOCIATED OROGENIC MOVEMENTS IN THE LATE PALEOZOIC STRATIGRAPHIC SUCCESSION OF NORTH AMERICA

TRIASSIC		
"PERMIAN"	*Widespread but inconspicuous unconformity. No definitely known orogeny*	
	Leonard-Capitan; Clear Fork-Double Mountain; Cimarron	
	Angular unconformity in west Texas	?APPALACHIAN OROGENY?
	Big Blue; U. Cisco-Wichita; Wolfcamp; U. Monongahela-Dunkard	
	Widespread but mostly obscure unconformity	MARATHON OROGENY
PENNSYLVANIAN	Virgil; U. Canyon-L. Cisco; Conemaugh-Monongahela (part)	
	Widespread unconformity	ARBUCKLE OROGENY
	Missouri; U. Strawn-L. Canyon; Conemaugh (part)	
	Widespread unconformity	
	Des Moines; L. and M. Strawn; U. Pottsville-Alleghany	
	Widespread unconformity	WICHITA OROGENY
	Morrow; Bend, L. and M. Pottsville	
	Widespread unconformity. Uplift of Appalachia and Llanoria	
MISSISSIPPIAN	Chester	
	Widespread unconformity	
	St. Louis-Ste. Genevieve	
	Widespread? unconformity	
	Osage	
	Widespread unconformity	
	Kinderhook (including Chattanooga)	
	Widespread unconformity	
DEVONIAN		

Pre-Kinderhook diastrophism.—In most parts of North America the basal Mississippian deposits are separated from the Devonian or older rocks by a very evident unconformity. Almost everywhere, however, the rocks above and below the break are parallel and it is only when regional relationships are noted that the magnitude of the

unconformity is evident. For example, a north-south section across the Oklahoma and Kansas portion of the Mid-Continent region shows the basal Mississippian (Chattanooga shale) successively resting on all formations from Devonian to Lower Ordovician. Similarly, in the type region along the Mississippi River in northeastern Missouri, western Illinois, and southeastern Iowa, the Kinderhook in different places overlies various formations of the Devonian, Silurian, and Ordovician systems (28, p. 33). In southeastern Missouri there was post-Middle Devonian faulting which resulted in the down-dropping of blocks of Devonian, Silurian, and other rocks several hundreds of feet. This was followed by erosion that removed all Devonian and Silurian rocks except in the depressed fault blocks and cut away part of the Ordovician strata of the upthrown areas. Early Mississippian deposits were spread over the eroded blocks of uplifted and down-faulted strata, and accordingly are found resting on Devonian, Silurian, or Ordovician rocks in different places.

The base of the Mississippian is not clearly defined in the Ohio Valley region, where in southern Indiana, Kentucky, and Ohio black shale (Chattanooga) that is regarded as Mississippian rests with apparent conformity on black or gray shale that is thought to be of Upper Devonian age. Changes in the conditions of sedimentation are indicated at about this horizon by the widely distributed reddish Bedford shale and by the Berea sandstone which occurs next above the Bedford. The Bedford is interpreted by some as indicating exposure and oxidation of latest Devonian sediments, and the Berea as marking the initial somewhat coarser clastic deposits at the base of the Mississippian system.

In the Appalachian geosyncline the beginning of Mississippian sedimentation is marked by thick sandstones and conglomerates (Pocono, Cattaraugus) which overlie Upper Devonian beds classed as Catskill or Chemung. The borderland, Appalachia, lying east of the Appalachian geosyncline, was strongly elevated in Middle Devonian time and resulting from this are the coarse subaerial clastic deposits that are included in the Catskill formation (Middle and Upper Devonian). Mississippian time appears to have been inaugurated in this region by a renewal of elevation of the geanticlinal area that resulted in the spreading of new deposits of land waste in the geosyncline.

The region of the maritime provinces in eastern Canada was subjected to profound orogenic movement accompanied by much igneous activity in post-Middle Devonian pre-Mississippian time. This is known as the Acadian orogeny. There is evidence that the folding

occurred before Late Devonian time, and in any case pre-Kinderhook erosion had reduced the land to moderately low relief. The Horton Bluff formation which is classed as Kinderhook contains conglomeratic basal beds and the lower 650 to 2,000 feet of beds are mainly feldspathic grits, but these do not indicate existence of near-by mountains (3). The upper 1,400 feet of the Horton Bluff beds consist of sandy or clayey shale.

Pre-Osage diastrophism.—A widespread unconformity separates the Kinderhook series from succeeding Mississippian rocks. The Osage group, characterized especially by limestone deposits in which variety and abundance of crinoidal remains, and in many regions abundance of chert, are extraordinary features, comprises the oldest post-Kinderhook beds. The unconformity at the base of the Osage group is shown chiefly by the absence of varying amounts of the upper Kinderhook in different sections and by the extensive overlap of early Osage deposits on older rocks (28, p. 142). Only locally, as on the south and east sides of the Ozark uplift, is there angular unconformity, and this does not appear to be of special significance. No orogenic movements of post-Kinderhook pre-Osage date are known in any part of North America, nor is it established that there were definite uplifts or warping movements of the continent at this time. The evidence rather points to relative lowering of sea-level that caused a temporary withdrawal of marine waters from the interior of the continent and accordingly produced a more or less well marked stratigraphic differentiation of the Kinderhook and succeeding beds.

Along the southwestern and southern flanks of the Ozark uplift, the basal Osage (St. Joe) beds rest unconformably on various parts of the Kinderhook series or on pre-Mississippian rocks. The Arbuckle Mountains of southern Oklahoma contain lower Osage limestone (Weldon) that rests unconformably on early Kinderhook (Woodford) shale and chert. Osage limestones have also been discovered in places at the borders of the Llano Uplift in central Texas, the immediately underlying rock in most places being of Early Ordovician age. In southern New Mexico, early Osage limestone (Lake Valley) rests disconformably on Devonian shale. Elsewhere in the western United States, there is very widespread thick limestone (Madison, Redwall) that is chiefly of Osage age but may include some Kinderhook beds, and these Early Mississippian deposits lie unconformably on Devonian to Cambrian rocks.

Pre-St. Louis diastrophism.—Whether or not the St. Louis limestone and equivalent deposits are separated from preceding Mississippian formations by an unconformity sufficiently widespread and

important as to time value of the hiatus to justify designation of this as a significant break, is uncertain. There is no doubt as to pre-St. Louis interruption of sedimentation in parts of the central Mississippi Valley region, and there is similar but less definite evidence in the Ohio Valley and Appalachian region. Throughout much of the western United States, Lower Mississippian limestone (Madison and equivalents) of Osage age is separated from Upper Mississippian limestone and shale by a pronounced stratigraphic break. The Upper Mississippian rocks of the west have not yet been correlated very definitely with subdivisions of the standard Mississippi Valley section, but St. Louis and Ste. Genevieve time are known to be represented in many sections and the Chester is also developed in some areas. Physical as well as faunal evidence of the unconformity between the Lower and Upper Mississippian rocks is very clear in many localities.

We may recall here that Ulrich (39), Schuchert (35), and some others have proposed a division of the Mississippian rocks into two co-ordinate parts that have been designated variously as series or as independent systems. The name Waverlyan has been used for the lower division, and Tennessean for the upper divison. In the most complete sections, the boundary between Waverlyan and Tennessean has been placed above the Keokuk limestone, classed as the uppermost part of the Osage group, and below the Warsaw limestone, classed as the basal part of the Meramec group. I have offered reasons for dissenting from this classification (28, p. 229), and may now express again the conclusion that if there is really a significant stratigraphic break in the Middle Mississippian succession, it belongs above rather than below the Warsaw (and Salem) beds.

There is no known evidence in North America of orogenic movements in the part of Mississippian time that immediately preceded deposition of the St. Louis limestone. Diastrophism of the epirogenic type, expressed only by movements of the strand line, is evidenced and it is not yet determined that these movements are of major importance. A reason for giving attention to possibility of a significant pre-St. Louis break is the marked change in paleontologic characters that appears here, and the widespread differentiation of Tournaisian (Kinderhook and Osage) from Viséan (St. Louis, Ste. Genevieve, and possibly part of Chester) subdivisions of the Lower Carboniferous abroad.

Attention may be directed to conditions observed in the New Brunswick and Nova Scotia region, where the Lower Mississippian Horton Bluff formation is succeeded unconformably by nonmarine arkosic grits of the Cheverie formation (700 feet), and this in turn

is overlain with little if any break by the marine Windsor series (1,100 feet). It is difficult to correlate the Windsor fauna with that of beds in the Mississippi Valley region, but close correspondence with the lower Viséan (*Seminula* and lower *Dibunophyllum* zones) of England is indicated (3, p. 169). These British Lower Carboniferous beds are characterized by the presence of the coral *Lithostrotion* which is also a guide fossil of the St. Louis limestone in North America. Although Bell (3, p. 173) has suggested correlation of the Windsor beds with the Ste. Genevieve and lower Chester rocks of the United States, it seems entirely possible that the Cheverie and Windsor deposits may correspond to St. Louis and Ste. Genevieve and that the pre-Cheverie break may be compared to the boundary at the base of the St. Louis formation. There was apparently epirogenic movement but no folding after Horton Bluff and before Cheverie time.

Pre-Chester diastrophism.—The Chester series is separated from older rocks in almost every known section by an unconformity, but as in the case of other breaks within the Mississippian system, evidence is lacking of orogenic movements belonging at this time. The record of sedimentation in Medial and Late Mississippian time is most nearly complete in the southern Illinois and western Kentucky region, but even here the basal Chester (Shetlerville) is found resting on different portions of the Ste. Genevieve limestone, and in several places there are deposits of conglomerate or sandstone at the contact. Farther east and southeast, as in West Virginia, Tennessee, and Alabama, where Late Mississippian deposits are of great thickness, the relations of the Chester to underlying stratigraphic divisions are not satisfactorily determined. The Greenbrier limestone includes beds of Chester age in its upper part, but lower parts of this composite unit in some localities are referred to the Ste. Genevieve, St. Louis, and even Warsaw horizons. The Mauch Chunk beds, consisting largely of sandy shale in which brownish red colors are relatively prominent, are classed as Chester in age. The thickness of the Mauch Chunk ranges up to about 3,500 feet in southeastern West Virginia.

On the south flank of the Ozark uplift, various horizons of the Boone limestone of Osage age are unconformably overlain by Chester deposits. The Moorefield shale of this region has generally been classed as belonging to the Meramec group, that is, equivalent in age to some part of the St. Louis or Ste. Genevieve limestones. There is no evidence, on the other hand, either in stratigraphic relations or character of fauna, which opposes assignment of this formation to the Chester series, and present understanding of the time significance of certain ammonoids that occur in the Moorefield fauna indicates rather defi-

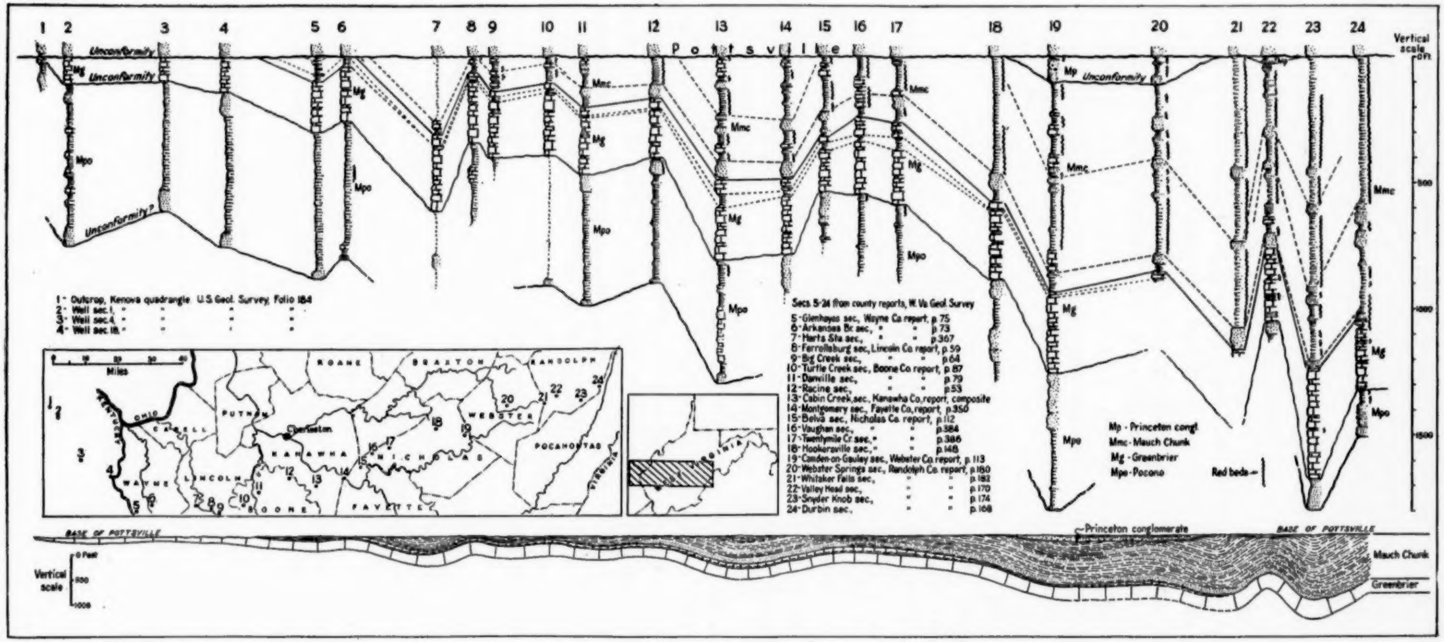


FIG. 6.—Geologic section showing unconformity between Mississippian (Chester) and Pennsylvanian rocks in Kentucky and West Virginia. (Data from U. S. Geological Survey and West Virginia Geological Survey.)

nitely that this shale should be considered as part of the Chester. If the Moorefield shale is thus classified, there are no known representatives of the St. Louis or Ste. Genevieve formations in the southern Ozarks. Evidence that the St. Louis limestone was once spread over part of this region, at least, is found in the presence of a few distinctive St. Louis fossils that occur as silicified loose shells or molds in residual chert concretions lying on the surface of the Boone limestone. In the Joplin region of southwestern Missouri large sink holes, caves, and underground passageways of various sorts were dissolved in the Boone limestone in pre-Chester time and these cavities were then filled by Chester deposits.

The Arbuckle Mountains region in southern Oklahoma contains thick shale (Caney) and limestone (Sycamore or "Mayes") deposits of Chester age that rest unconformably on Early Mississippian limestone (Weldon), belonging to the basal Osage, or dark shale and chert (Woodford) of Kinderhook age.

Chester deposits (Barnett shale) occur on the flanks of the Llano Uplift in central Texas, resting unconformably on thin remnants of Early Mississippian Osage limestone or on Ordovician limestone (36, p. 92).

The Hueco Mountains, in extreme western Texas, contain Chester (upper Helms) beds that lie unconformably on early Osage (?) strata and possibly on Devonian (19; 36, p. 94).

Late Mississippian deposits in the western part of the United States are mostly not well enough known to permit definite statement as to stratigraphic relations. Beds containing undoubted Chester fossils are known in southeastern Arizona (Paradise formation) and they rest without observed evidence of stratigraphic hiatus on strata that are correlated with the Ste. Genevieve limestone. From widely distributed limestones that have been studied in a preliminary way at places in Nevada, Idaho, Montana, and Utah, faunas that are tentatively correlated with the Salem, St. Louis, Ste. Genevieve, and Chester beds of the Mississippi Valley region have been reported, but the stratigraphic distribution and relationships are not very definite.

At the northern extremity of the Appalachian belt, in New Brunswick and Nova Scotia, the Hawkesbury series, consisting of some 5,000 feet of red and greenish gray shale and sandstone, is reported to lie conformably on Windsor beds in some places and elsewhere to rest unconformably on these or older rocks. There is no evidence of orogenic movements in pre-Hawkesbury time, although the great thickness and the clastic character of the Hawkesbury deposits indi-

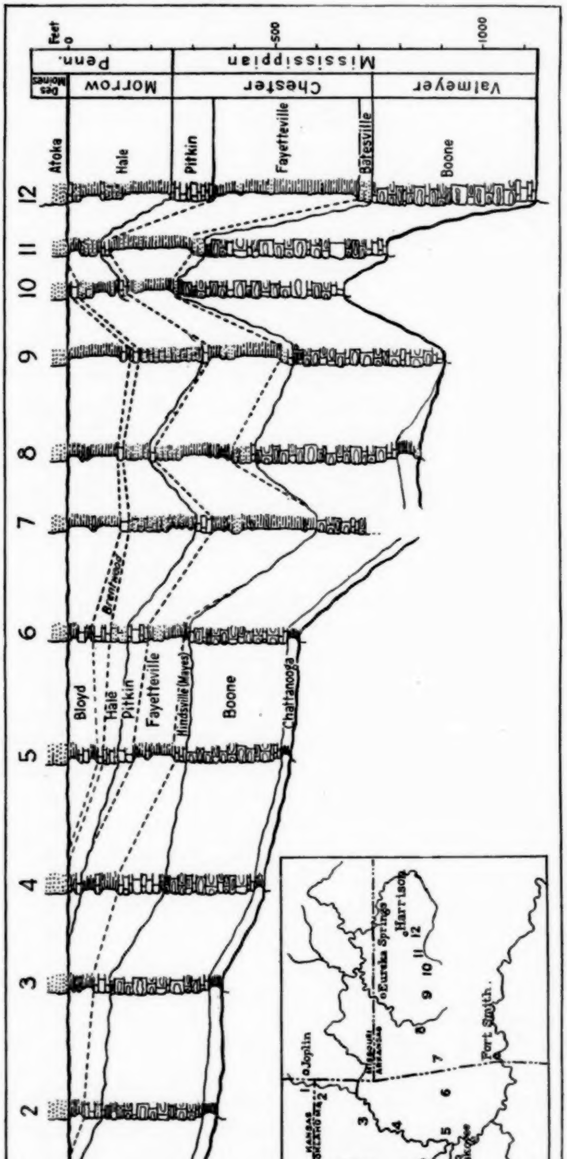


FIG. 7.—Geologic section showing stratigraphic relations of Mississippian and Lower Pennsylvanian rocks in northeastern Oklahoma and northwestern Arkansas. (Data from U. S. Geological Survey and Oklahoma Geological Survey.)

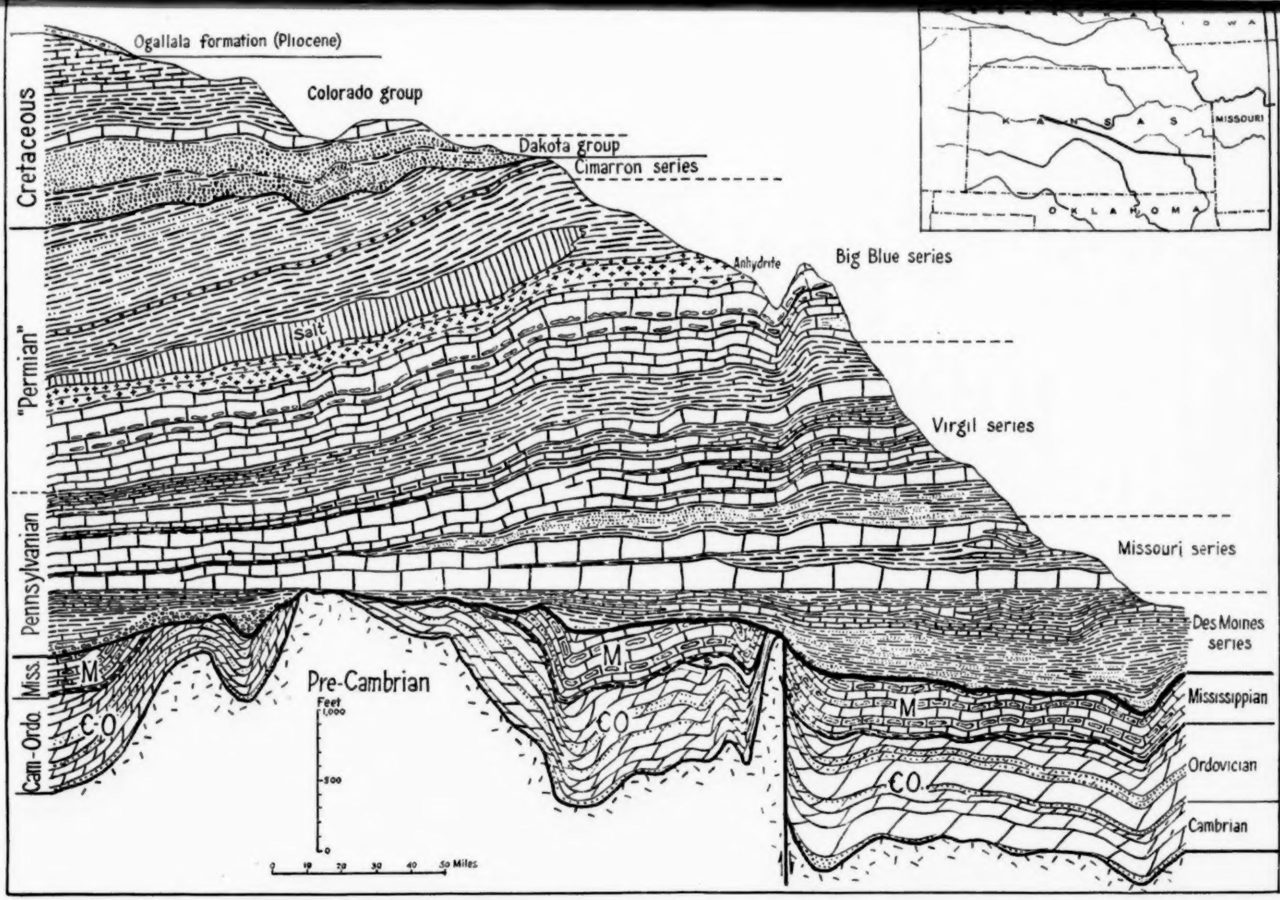


FIG. 8.—Diagrammatic geologic section across part of Kansas, showing stratigraphic relations of Late Paleozoic rocks. Drawn on base of Bronson group as datum. (Data from section by Betty Kellett, Kansas Geological Society.)

cates existence of uplands that underwent much erosion. Fossils are not abundant, but because the underlying Windsor beds have been correlated in part with the Chester series, it has been concluded that the Hawkesbury belongs at the base of the Pennsylvanian. On the other hand, it is also correlated with the lower Namurian of Europe, which is Chester. All things considered, it seems possible that the Hawkesbury beds may be Chester rather than later in age.

A feature of the Chester deposits that is well defined in the central and part of the eastern United States is the beginning in this series of distinctively rhythmic sedimentation in which there is a definite alternating succession of coarse and fine, clastic and nonclastic, littoral or nonmarine, and marine offshore sediments. This cyclic oscillation may have diastrophic significance, and it certainly has stratigraphic importance.

Pre-Morrow diastrophism.—The Morrow series is typically developed on the southwestern flank of the Ozark uplift, in northwestern Arkansas and northeastern Oklahoma. The Morrow rests unconformably on different formations of the Chester series, and locally there is a coarse basal conglomerate. No evidence of pre-Morrow folding or even strong warping is seen in this region, however, for the beds above and below the unconformity are essentially parallel and the Morrow is not observed to overlap pre-Chester rocks. On the basis of invertebrates and plants the Morrow is classed as Lower Pennsylvanian and is correlated with the middle and perhaps a part of the lower Pottsville beds of the Appalachian geosyncline.

No deposits of Morrow age are known north of the southern Kansas boundary in the Mid-Continent region, but they are present throughout most of the country south and southwest of the type area as far as westernmost Texas. In the Ouachita Mountains, of southwestern Arkansas and southeastern Oklahoma, there is a very thick succession of clastic Carboniferous beds (Stanley, Jackfork, Johns Valley, Atoka) that is mostly lacking in determinable organic remains, but there is paleontologic and some stratigraphic evidence for the conclusion that most, if not all of these deposits, excepting the Atoka, are referable to the Morrow series. At the bottom of these formations that are tentatively regarded as Morrow in age there is, in part of the area, a basal conglomerate and sandstone (Hot Springs) that rests unconformably on Early Mississippian novaculite. The strongly clastic character and thickness of these deposits between the novaculite and the Atoka, reported to attain a maximum of more than 10,000 feet, indicate the occurrence of important elevation of a land mass (Llanoria) lying south of the Ouachita geosyncline (25,

26), and the diastrophism thus indicated may be assigned, until we have contrary evidence, to pre-Morrow time.

On the north and south flanks of the Arbuckle Mountains uplift, lying west of the Ouachitas in south-central Oklahoma, rocks of Morrow age include fairly thick shale and sandstone, and some limestone beds (Springer, Wapanucka, lower Dornick Hills) (21). The basal part of this succession consists of dark shale that is only slightly different in lithologic characters from black shale (Caney) of Chester age which underlies the Pennsylvanian shale with parallel structure. The contact between these shales presumably represents an important unconformity. It can be located in favorable exposures, but it is very inconspicuous.

The Bend group of north-central Texas, restricted to exclude the shale (Barnett) of Chester age, which underlies it, represents the Morrow series in this region. The lower half of the Bend consists of massive limestone (Marble Falls), 400 to 600 feet thick, and this limestone rests with parallel structure on the underlying Chester shale or in places overlaps onto Early Mississippian or Ordovician limestones. There is no basal conglomerate or other clastic materials at the bottom of the Bend section, and excepting the localities where overlap is evident, there is no physical indication of the stratigraphic break that must be inferred to exist at the base of the Bend limestone (30).

Beds of Morrow age are present in the Trans-Pecos region of western Texas, and according to recently gathered information appear to include, in the Marathon region, the thick Tesnus shale and sandstone, Dimple limestone, and probably the lower part of the Haymond formation. The Tesnus rests unconformably on novaculite of Devonian (?) age, and it thins markedly and overlaps northwestward (20). The evidence points to occurrence of a pre-Tesnus uplift of a crystalline land mass lying southeast of the Marathon geosyncline. The Hueco Mountains, still farther west, contain Morrow (?) limestone and shale that rests with parallel structure on rocks of Chester age (upper Helms) (19). An unconformity is probably present.

Deposits of Morrow age are not known in New Mexico, Arizona, nor in the more northerly western states, except possibly in Montana.

Turning to the eastern part of the United States, distinctive Morrow fossils have been discovered in the lower part of the group of beds classed as Pottsville in southern Illinois (reported by J. M. Weller). The Pottsville of this region is mostly clastic, contains thick sandstones and some coarse conglomerates, and rests with marked unconformity and overlap on Chester or older rocks. Accordingly,

some warping and probably considerable erosion preceded the beginning of sedimentation of Morrow age in this region. Whether the prominent La Salle anticline, which trends approximately north to south across eastern Illinois, was formed in pre-Morrow time or slightly later is not certain, but the folding along this line appears to be post-Mississippian and earlier than Alleghany or Des Moines time.

Throughout the Appalachian geosyncline the Pottsville deposits are set apart from the underlying Mauch Chunk or other Mississippian beds by pronounced lithologic differences, including especially the occurrence in the Pottsville of numerous coarse sandstones and conglomerates. Cobbles up to 6 inches in diameter occur in some of the lower Pottsville conglomerates. Local exposures in most places show that the beds above and below the base of the Pottsville are parallel, but regional study makes clear that there is an important unconformity at this horizon. Some of the westward thinning of Upper Mississippian deposits beneath the Pottsville is an original feature, but there are also evidences of pre-Pottsville erosion such as truncation of gentle folds in the Mauch Chunk strata (Fig. 6). In places the Pottsville overlaps onto Middle or Early Mississippian rocks, but this part of the Pottsville is probably younger than Morrow. If the middle (New River) and lower (Pocahontas) parts of the Pottsville are mainly, or entirely, of Morrow age, it is evident that pre-Morrow time was marked in the Appalachian region by an important elevation of the land mass lying east of the geosyncline, but whether this movement involved folding of the rocks in the borderland (and perhaps the eastern part of the geosyncline) or only strong vertical uplift is not known.

There is evidence of orogenic movements in eastern Canada which probably belong to pre-Morrow time, but correlations of the beds above and below unconformities are not sufficiently definite to permit certainty of conclusions. Above the Hawkesbury series, which is thought to correspond to the lower Namurian (Chester), is the Cumberland series, consisting of coarse boulder conglomerate, sandstone, shale, and coal, with total thickness of about 7,000 feet. The flora contains *Neuropteris* of the *N. schlehani* group and other forms that occur in the lower and middle Pottsville and Morrow beds. The fossil plants from the Lancaster formation ("Fern Ledges") near St. John, New Brunswick, which is correlated with the Cumberland series, appear to correspond most closely to forms in the upper Pottsville, however. Basal conglomerates, locally 2,600 feet thick, rest on folded older Carboniferous or pre-Carboniferous rocks, but there are some places where the underlying beds are parallel to the Cumberland de-

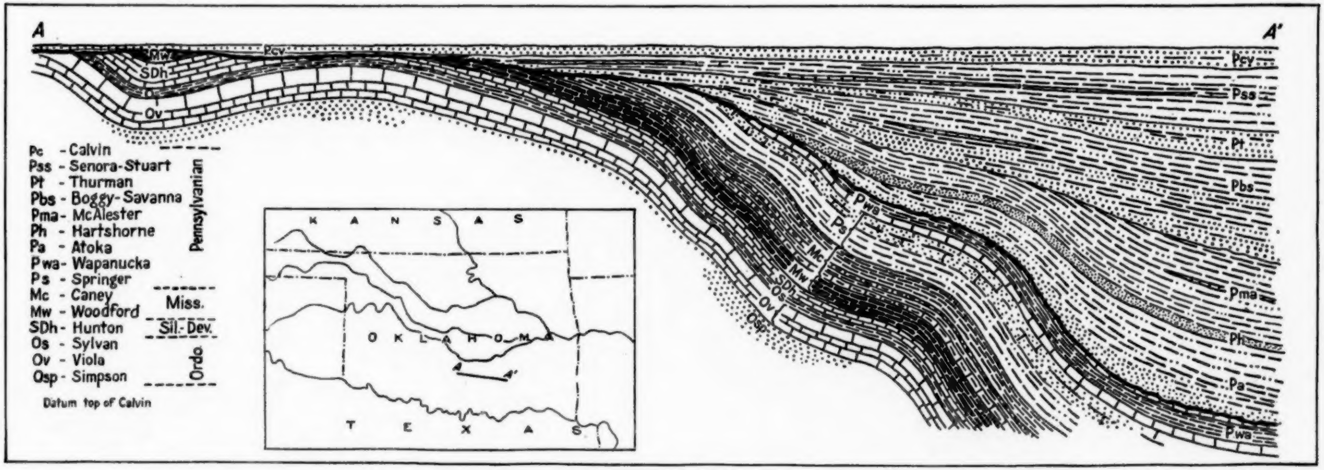


FIG. 9.—Geologic section along north flank of the Arbuckle Mountains (line A-A′) showing unconformities and overlaps in Pennsylvanian rocks. Heavy line represents boundary between rocks of Morrow and Des Moines age. (Drawn from surface and subsurface data.)

posits. It is clear that there was very considerable topographic relief in this region in early Cumberland time, and this is similar to conditions observed throughout the part of the Appalachian trough that lies in the United States in early Pottsville time.

The southern end of the Appalachian trough, in Alabama, contains 1,000 feet or more of shale and sandstone (Parkwood) that appear to underlie conformably the lowest beds classed as Pottsville in this region. The exact age of these beds, which overlie fossiliferous upper Chester deposits, is not determined, but they are generally regarded as transitional between Mississippian and Pennsylvanian.

Pre-Des Moines diastrophism.—The Des Moines series is typically developed in the northern part of the Mid-Continent region, comprising groups called Cherokee and Marmaton, but strata of equivalent age are among the most widespread of Pennsylvanian deposits in North America. The Des Moines beds are distinctly unconformable on the Morrow rocks of the southwestern flank of the Ozarks, for sandstone or conglomerate of the basal Des Moines is found resting in various places on very different stratigraphic portions of the Morrow series. The Des Moines also rests unconformably on Chester, Meramec (St. Louis, Ste. Genevieve), Osage, and Kinderhook divisions of the Mississippian system, and overlaps onto Devonian, Silurian, Ordovician, Cambrian, and pre-Cambrian rocks. Broadly speaking, the pre-Des Moines unconformity is one of the most clearly defined and widely recognizable stratigraphic breaks in the Late Paleozoic succession of the Mid-Continent region. It is strikingly evident beneath the surface also, as indicated by study of well borings, and it is now clearly established that the important uplift along the Nemaha Granite Ridge axis, extending from the vicinity of Omaha, Nebraska, to somewhat south of Oklahoma City, Oklahoma, is of pre-Des Moines (and probably but not certainly post-Morrow) age.

The thickness and proportion of clastic sediments in the Des Moines rocks increases markedly southward from northern Oklahoma. The Atoka and younger Pennsylvanian deposits of southeastern Oklahoma and west-central Arkansas, in the Arkansas Valley and Ouachita Mountains areas, are all, or practically all, of Des Moines age. Fossils collected from parts of the Atoka formation, as mapped, are definitely of Des Moines type, but in some places, also mapped as Atoka, the fossils obtained appear to indicate Morrow age. Accordingly there is some question, at present, concerning the lower boundary of the rocks of Des Moines age, and this statement applies to the so-called Atoka on the north flank of the Arbuckle Mountains also. The occurrence of thick coarse conglomerates containing pebbles of

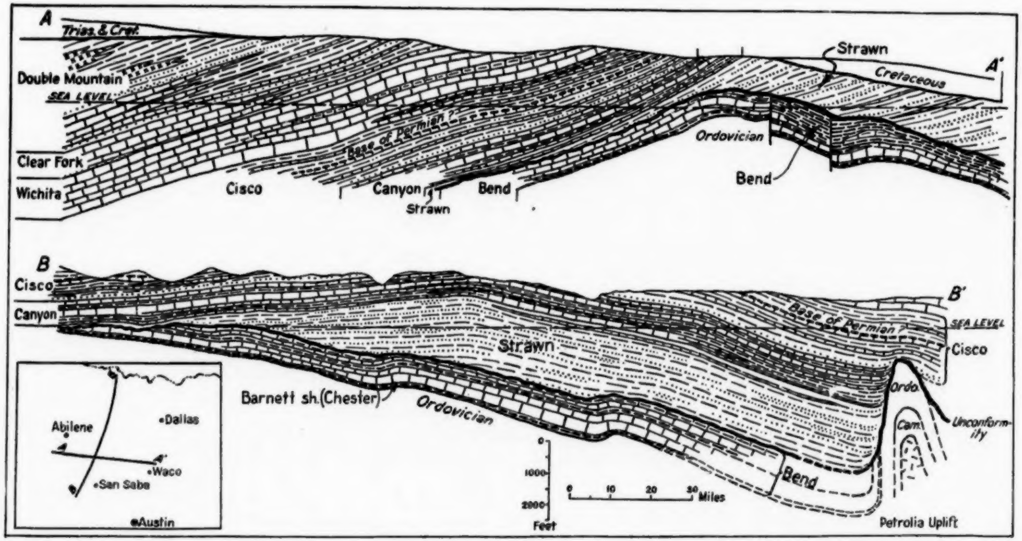


FIG. 10.—Geologic sections across north-central Texas showing stratigraphic and structural relations of Morrow (Bend) and associated rocks. Discordance in structure of Bend and younger rocks is clearly evident. (Data from sections by M. G. Cheney, Texas Bureau Economic Geology.)

Ordovician and other pre-Pennsylvanian limestones, at or near the base of the Des Moines beds in this region, and overlap of lower Des Moines formations toward the Arbuckle Mountains, are evidences of diastrophism that probably involved some folding and faulting of pre-Des Moines rocks.

On the south side of the Arbuckle Mountains, in the Ardmore basin, definitely identifiable Des Moines fossils first appear in sandstone and shale that currently are classed in the upper part of the Dornick Hills formation (Pumpkin Creek member and below). Underlying parts of the Dornick Hills (Lester, Bostwick, Otterville) beds contain faunas of Morrow aspect, but in places they also contain much conglomeratic material that evidences uplift and erosion of pre-Pennsylvanian rocks in an area on the south (including the Criner Hills) that is structurally a continuation of the Wichita Mountains (38). The exposed part of the Wichita Mountains lies west and slightly north of the Arbuckles. There is probably a disconformity at the base of the Des Moines strata in the Ardmore Basin, but the conformity of structure with underlying Pennsylvanian beds and the absence of conglomerates in the lower Des Moines deposits of this region, imply absence of important local diastrophism of pre-Des Moines age in this region. As in neighboring areas, however, the Des Moines section of the Ardmore basin is very thick and is characterized by prominence of sandstones, which argues for occurrence at this time of a considerable uplift in the source region of these sediments, presumably at some distance farther southeast.

No stratigraphic or structural discordance in the Late Paleozoic rocks of the Mid-Continent region appears more evident over a widespread area than that at the base of the Des Moines strata in north-central Texas. This boundary separates the Smithwick or Marble Falls rocks of the Bend group, below, from the Strawn group, above. The Bend strata, comprising thick limestone and fine-grained dark shale, were warped, displaced several hundreds of feet in many places by faulting, and subjected to an undetermined amount of erosion before the beginning of Strawn deposition (11, 30). The Strawn beds, consisting mainly of sandy shale and sandstone, differ in dip and strike from the underlying rocks, and they exhibit a pronounced westward overlap. At some horizons there are prominent conglomerates. Subsurface studies in northern Texas indicate that the Strawn rests in places with angular unconformity on Bend, Ordovician, Cambrian and pre-Cambrian rocks (11). The occurrence of pre-Des Moines diastrophism in this region is indicated, therefore, both by the stratigraphic-structural relationships to the older rocks, and by the

considerable thickness of coarse clastic sediments in the Strawn group. The latter indicates a crustal movement involving fairly strong uplift in the source region of the sediments, lying on the east. The materials in some of the Strawn conglomerates appear to have come from formations of the southward extension of the Ouachita geosyncline,

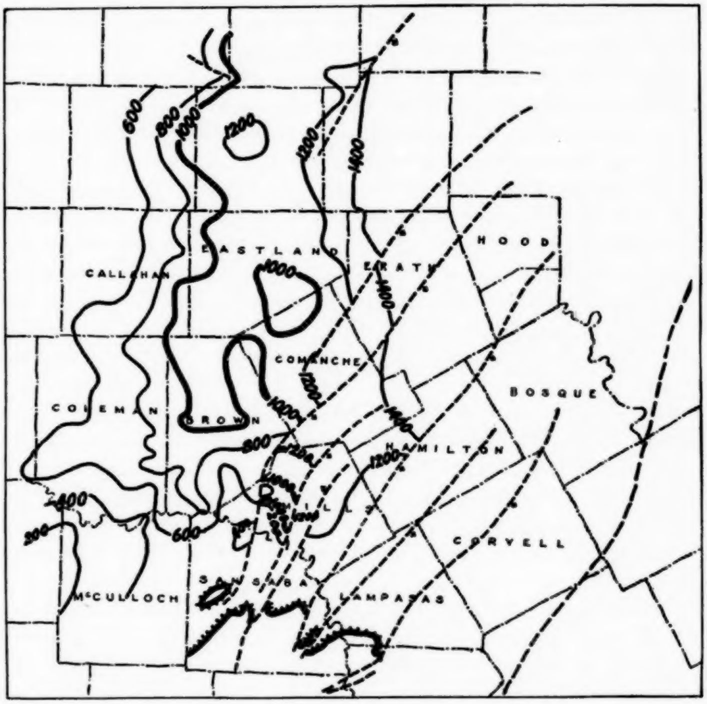


FIG. 11.—Map of part of north-central Texas showing thickness of Bend and Barnett beds. Warping and faulting affected Bend rocks in late Morrow or post-Morrow time and a moderately smooth surface was developed by erosion before beginning of Des Moines (Strawn) sedimentation. (Data from M. G. Cheney, Texas Bureau of Economic Geology.)

which is indicated by information from deep wells and other evidence to be continuous around the southeast side of the Llano uplift with the Marathon geosyncline of western Texas (27).

The Marathon region of Trans-Pecos Texas contains beds that have yielded distinctive Des Moines fossils. These occur in the upper part of the Haymond formation and the lower part of the Gaptank

formation. Neither the lower nor the upper boundaries of the strata equivalent to the Des Moines are known precisely, but it appears reasonable to suggest that the zone of very coarse conglomerate and of scattered small to huge boulders approximately 400 feet below the base of the Gaptank beds belongs at or near the base of the Des Moines (2). This agrees with paleontologic evidence, so far as known, and if such definition of the boundary is correct, there is indication of an important pre-Des Moines stratigraphic break in the west Texas region. In the area where the conglomerate and boulders appear, these deposits, associated with much coarse arkosic sandstone, are conformable in structure with underlying Haymond strata. Identification of many of the boulders as representing pre-Pennsylvanian rocks of several sorts, including known Ordovician and other sedimentary units of the Marathon geosyncline on the south, furnishes proof that the formations from which the boulders were derived were exposed at the surface at this time. It is inferred that folding, possibly accompanied by faulting, affected parts of the Marathon geosyncline in pre-Des Moines time, and according to belief of geologists who have specially studied the problem, the boulders were spread out through the agency of ice.

Farther west in Trans-Pecos Texas, beds of Des Moines age have been found in the Sierra Diablo. Locally they overlie rocks containing Morrow fossils (1), the nature of the contact being unreported. In the Hueco Mountains, several hundred feet of limestone and shale of Des Moines age rest with clearly evident unconformity on beds of Morrow age, but the beds above and below the break are essentially parallel (19).

Morrow beds are absent in most of New Mexico, but deposits of Des Moines age (lower Magdalena) are widespread. They rest unconformably on Early Mississippian or older rocks. In southeastern Arizona the lower Naco limestone, containing Des Moines fossils, rests disconformably on Chester limestone and shale. Similar relations exist at many places in Nevada, Utah, Idaho, Montana, Wyoming, and Colorado, but there are many sections also in which the rocks next below the Des Moines strata are Lower Mississippian. The lower part of the Pennsylvanian deposits in the Black Hills region of South Dakota contains Des Moines fossils, the next underlying formation being Lower Mississippian. There is thus evidence of extremely widespread pre-Des Moines erosion in the western United States, but indication of pre-Des Moines folding is not found.

The lower boundary of the rocks of Des Moines age is not yet determined with precision in the eastern part of the United States,

but the location of the boundary is approximately known and it will very probably be possible to mark it exactly by future work. Des Moines fossils occur in the Alleghany group and extend from above the middle of the Illinois Pennsylvanian almost to the base of the Pottsville section, but the Pottsville of Illinois represents only the upper part of this division as defined in the Appalachian trough. The initial Des Moines deposits in the Appalachian region are probably marked by one of the persistent conglomerate and sandstone parts of the upper Pottsville (probably the Sharon conglomerate), and although the beds are essentially parallel, it is expectable that a disconformity of time value greater than that assignable to the many other local stratigraphic breaks in the Pennsylvanian of the east, occurs at the bottom of the deposits of Des Moines age. Pottsville time was characterized by a number of successive uplifts of the old-land that lay east of the area of thick sedimentation. One of these crustal elevations may coincide in time with the diastrophism of pre-Des Moines age that is evidenced elsewhere in the continent. Later Des Moines time in the Appalachian region was marked by relatively little deposition of coarse materials (Alleghany) and the same is mostly true in other regions.

In New Brunswick and Nova Scotia the Pictou series, characterized by a large and distinctive flora like that of the upper Pottsville and Alleghany beds of the United States and the Staffordian and Radstockian of England, rests with well marked unconformity on the Cumberland series or older rocks. In places there are coarse basal conglomerates and much of the remaining part of the series, over 7,000 feet in greatest thickness, consists of arkose. The Pictou beds overlap extensively onto pre-Carboniferous rocks. Part or all of the thick Cumberland series was eroded in some areas before the beginning of Pictou deposition, but the crustal deformation in this region, fairly definitely classed as pre-Des Moines, was less pronounced than that preceding Cumberland (Morrow?) time.

The pre-Des Moines diastrophism appears to have involved orogenic disturbances, that is folding and faulting of Morrow or older rocks that next underlie the Des Moines, only in the southern Mid-Continent region. These movements affected parts of the Ouachita geosyncline, the northeastern part of the present Arbuckle Mountains, at least parts of the southeastward extension of the Wichita Mountains axes, the Llano uplift in central Texas, and parts of the Marathon geosyncline in west Texas. The term *Wichita orogeny* has been applied to deformative movements belonging at this time, and we may use it here, but is should be noted that movements of other

geologic dates are apparently evidenced in the Wichita Mountains belt, as they are also in the other southern Oklahoma and in the west Texas mountain uplifts.

Pre-Missouri diastrophism.—According to revised definition of the Missouri series, as proposed by the writer, the lower boundary is drawn at the widespread unconformity that is recognized in the shale and sandstone section between the Lenapah and Hertha limestones of Kansas or their equivalents. In parts of western and northern Missouri the entire upper half of the Des Moines series appears to have been eroded before the beginning of sedimentation belonging to the Missouri series, basal sandstones of which lie directly on Cherokee shale. A clearly defined change in the character of marine faunas is found to coincide with this stratigraphic break, which emphasizes correspondingly the importance of the boundary. There is no structural discordance, however, between the Missouri series and the underlying rocks in the northern Mid-Continent region, for the bedding planes above and below the unconformity are essentially parallel.

The base of the Missouri series is not strongly defined by physical evidence in southern Kansas, but it is marked for a long distance in Oklahoma by sandstone deposits in the lower part of the so-called Coffeyville formation. This sandstone rests on different horizons of the upper Des Moines beds and there appears to be some evidence of northward overlap of the basal Missouri deposits. In southern Oklahoma the Seminole conglomerate forms the lowermost part of the Missouri series. Evidence of overlap of this formation in the direction of the mountain uplifts on the south is not observed, however.

The boundary between the Missouri and Des Moines series is not as yet exactly located in the thick Pennsylvanian deposits of the Ardmore Basin on the south side of the Arbuckle Mountains, but fossils of the lower Hoxbar indicate Missouri age, while collections from the uppermost Deese represent the Des Moines series. The contact belongs, therefore, near the boundary between Hoxbar and Deese.

In north-central Texas paleontologic evidence shows that most of the Strawn group is of Des Moines age, the upper boundary of this series belonging not lower than the top of the East Mountain shale. Fusulinids reported from the Lake Pinto sandstone (41) and higher parts of the Strawn are types found characteristically in the Missouri series, and the base of this series in the north-central Texas section, therefore, may be drawn tentatively at the base of the Palo Pinto sandstone. There is no distinct evidence of an unconformity at this horizon, but the detailed stratigraphy of the Strawn deposits in the

geographically separated outcrops of the Brazos and Colorado valleys is insufficiently known.

The lower part of the Gaptank formation in the Marathon region of western Texas is definitely of Des Moines age. The middle part of this formation, separated by conglomerates from the fossiliferous lower beds, is probably equivalent to the Missouri series, but paleontologic evidence is not conclusive. As a matter of fact, there are a number of conglomeratic horizons and it is not known which if any of these are specially significant as to existence of this stratigraphic break. Fossils of Upper Pennsylvanian age (Virgil series) occur in the upper Gaptank.

Stratigraphic and paleontologic studies of the Pennsylvanian rocks of the western United States are at present wholly insufficient as a basis for statement concerning the possible presence and distribution of rocks of Missouri age. Recent studies of the Pennsylvanian section exposed in the Hartville uplift of eastern Wyoming indicate the presence of Missouri beds in this area (G. E. Condra) but definite evidence of physical breaks is not reported.

The upper part of the Illinois Pennsylvanian section, excluding probably the topmost sandstone (Merom), is correlated with the Missouri series on the basis of fossils, and also of identification by close stratigraphic comparison with adjacent outcrops in Missouri of subdivisions of the Des Moines series. The boundary between the Des Moines and Missouri is placed at the base of the Trivoli cyclothem (J. M. Weller and H. R. Wanless). The contact is a disconformable one, but because disconformities are recognized beneath so many of the Illinois cyclothems it can hardly be said that there is physical evidence of the special importance of this break.

Identification of the equivalents of the Missouri series in the Appalachian region is based partly on paleontologic evidence, but somewhat more on comparison with the Illinois section. Additional field work with the special object of establishing correlation of equivalent horizons in the Appalachian and Illinois basins is necessary. A horizon near the base of the Conemaugh, between the Upper Freeport coal and the Brush Creek limestone, is thought to correspond to the base of the Missouri series.

A survey of the evidence as to pre-Missouri crustal movements in the United States calls attention to a widespread physical break between Des Moines and Missouri rocks, indicating interruption of sedimentation and in places considerable erosion, but nowhere is there indication of orogenic movements at this time. This is rather surprising in view of the fact that perhaps no other boundary in the post-

Mississippian succession of Paleozoic rocks in North America is more definitely indicated paleontologically. In other words, the break appears to be one of especial importance, but there is, in general, little physical evidence of it.

Pre-Virgil diastrophism.—The Virgil series is defined on the basis of exposures in Kansas and can be differentiated readily throughout the northern Mid-Continent region. It comprises the uppermost part of the Pennsylvanian system, as this is currently defined, and includes most of the upper part of the "Missouri series" of older usage. The lower boundary of the Virgil series is marked by a widespread unconformity which in most places occurs near the top of the Stanton limestone or equivalent beds, but in southern Oklahoma reaches very much lower. The rocks below this unconformity belong to the Missouri series as restricted.

In Kansas and adjacent territory the basal deposits of the Virgil series consist of conglomerate, sandstone, or sandy shale that rests with distinct unevenness on an erosion surface developed across strata of the Peedee or Lansing groups. The entire thickness of the Peedee beds has been removed in some areas and locally the hard limestones of the upper Lansing have been cut away. In southern Kansas and northern Oklahoma the basal Virgil sandstones, partly marine but largely nonmarine, are especially prominent. They offer strong contrast in lithologic characters to the limestones and fine shales of the underlying Missouri series that in this region consists almost entirely of marine deposits.

On the north side of the Arbuckle Mountains in southern Oklahoma there is a considerable hiatus between the Belle City limestone or beds equivalent to the Ochelata formation and the unconformably overlying Vamoosa formation. The upper part of the Missouri series, including the Peedee, Lansing, and part of the Kansas City groups, is not represented here, and in addition the older part of the Virgil as developed farther north, is apparently absent. The Vamoosa consists of conglomerates, sandstones, and red beds that overlap toward the mountain uplift. In places, the coarsely conglomeratic Ada formation, or still higher beds above the Vamoosa, comprise the basal deposits of the Virgil series, resting with angular unconformity on Ordovician or other pre-Pennsylvanian rocks of the Arbuckles. The stratigraphic and structural relationships indicate that the strong folding and faulting that affects the formations of the Arbuckle Mountains are mainly due to orogenic movements of post-Missouri pre-Virgil date.

The Ardmore basin, as already noted, contains a great thickness

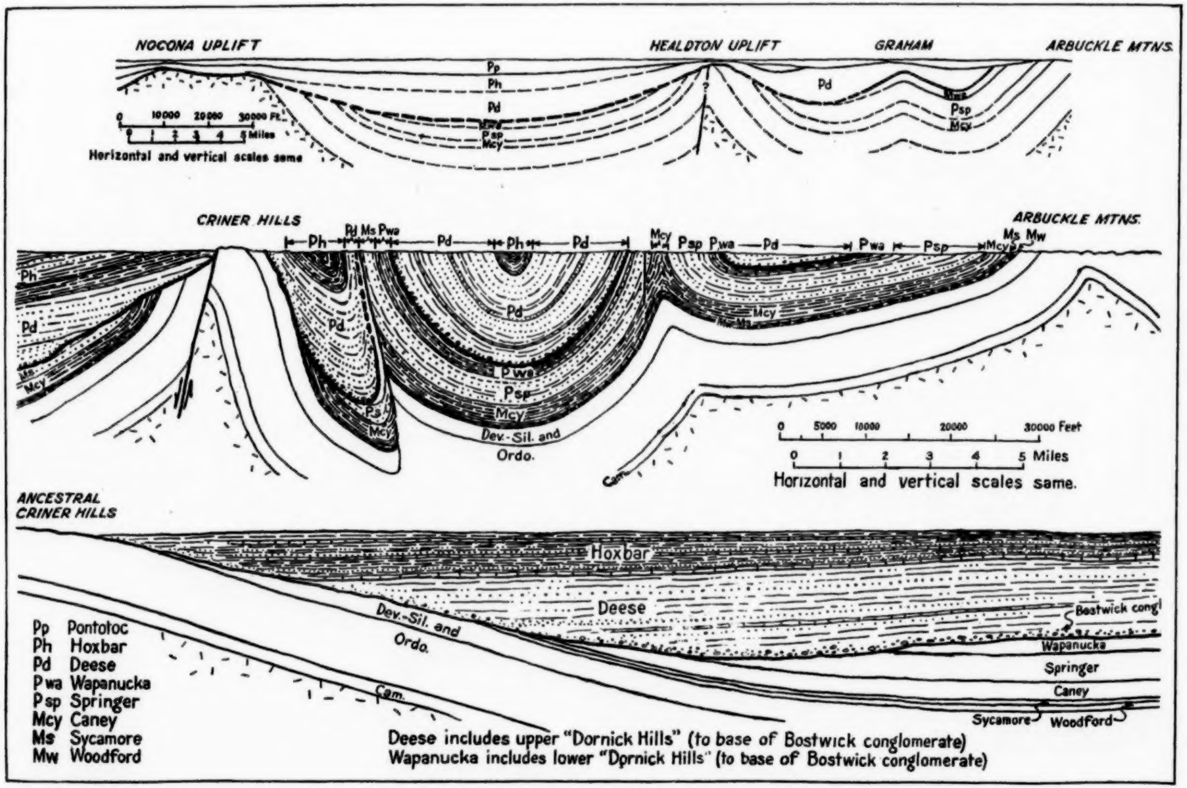


FIG. 12.—Geologic sections south of Arbuckle Mountains, Oklahoma. Upper section shows inferred relations between Morrow and younger rocks indicating post-Morrow pre-Des Moines deformation. Middle section represents structural relations of rocks in Ardmore basin and part of Arbuckle Mountains, date of folding being post-Hoxbar (post-Missouri). Lower section shows inferred structure and stratigraphic relations in Ardmore basin in late Missouri time. There are also some conglomerates in beds here called Wapanucka. (Data from C. W. Tomlinson, Oklahoma Geological Survey.)

of steeply folded Pennsylvanian rocks, the youngest part of which is included in the Hoxbar formation. Fusulinids and other fossils from the Hoxbar indicate Missouri age, and since the strong folding of the Pennsylvanian and underlying Paleozoics of the Ardmore basin and of the adjoining Arbuckle Mountains belongs certainly to post-Hoxbar time, it can be dated as younger than at least part of the Missouri series. As shown by surface outcrops and subsurface studies, the truncated Hoxbar and older rocks are overlain with great unconformity by conglomerates, red sandstones, and shales that belong to the Virgil series. It is reasonable to conclude that the main *Arbuckle orogeny* corresponds in time to that of the widespread break between the Missouri and Virgil series, and the deformation may thus be considered as post-Missouri and pre-Virgil.

It is believed that an unconformity, marking the boundary between rocks of Missouri and Virgil age, is almost surely present in the Pennsylvanian section of north-central Texas, as it is in the Ardmore basin south of the Arbuckle Mountains and also north of these mountains in Oklahoma, Kansas, and Missouri. The existence of such a break can not now, however, be affirmed. Available evidence from fossils is inconclusive, but it indicates that the boundary may belong in what is now called the Caddo Creek formation, for the Ranger limestone which underlies the Caddo Creek contains fossils of Missouri type, while the Home Creek limestone and other beds of the upper Caddo Creek, and the Graham formation, show paleontologic affinities with the Virgil series. An unconformity is known to separate the Graham and Thrifty formations (30), and a number of other unconformities that are strongly defined locally have been observed in the upper Canyon and lower Cisco groups north of the Brazos River. The question, therefore, appears to be whether one of these breaks may be deemed more important than the other. The pre-Virgil boundary should underlie the Graham formation, which comprises the basal part of the Cisco group and probably belongs below the Home Creek limestone, which as now classed belongs near the top of the Canyon group.

The occurrence of Virgil fusulinids and of a fauna containing *Uddenites* near the top of the Gaptank formation in the type section northeast of Marathon, western Texas, is basis for the conclusion that the Virgil epoch is represented by deposits in this region (20, 21, p. 697). The *Uddenites*-bearing beds were at one time included in the Wolfcamp formation, but it is now concluded that they underlie the Wolfcamp disconformably. The *Uddenites* fauna has been discovered to be present with typical characters in lower Cisco strata of north-

central Texas, and these are regarded as not older than Virgil. The stratigraphic boundary between rocks of this age and those assignable to the Missouri series is not determined, but it may possibly belong at the base of the "Fourth" or perhaps the "Fifth" conglomerate described in the upper part of the Gaptank. In any case, the beds containing Virgil fossils rest with parallel structure on older parts of the Gaptank formation in the outcrops northeast and north of Marathon. The Gaptank and older beds in the western part of the Marathon basin are very strongly folded and faulted. The presence of *Schistoceras hyatti, Uddenites, Triticites secalicus* and other fossils (23) in part of these steeply inclined strata indicates that the orogenic movements in this area are post-Virgil in age (20, p. 45), and therefore later than the Arbuckle folding.

At the present time little can be said definitely concerning the geographic distribution or stratigraphic limitations of deposits of Virgil age in the western part of the United States. Cephalopods and other fossils collected from part of the Abo sandstone in New Mexico indicate that the Virgil series is represented here (24), but most of the deposits classed as Abo appear to be younger. Absence of distinctive Virgil types of fusulinids or other diagnostic fossils throughout the western Pennsylvanian areas is negative evidence on which the conclusion has been reached tentatively that the series is not present. This is, at best, however, a very doubtful judgment.

It is probable but not certain that the topmost sandstone (Merom) of the Illinois Pennsylvanian section represents the basal clastic deposit of the Virgil series in this region. Chief reasons for this opinion are the correlation of subjacent beds with upper Missouri strata of the Mid-Continent area, and the relative prominence of this sandstone, suggesting the similarly prominent clastic deposits of the basal Virgil. The uppermost parts of the Pennsylvanian in Indiana and western Kentucky are probably also of Virgil age, but, if so, only a small part of deposits belonging to the series that originally may have been present now remains.

In the Appalachian region the Monongahela group corresponds fairly closely to the Virgil series, but neither the lower or upper boundaries of the two units are exactly equivalent.

It appears, then, from this brief review, that pre-Virgil diastrophism includes strong folding in the Arbuckle Mountains region of southern Oklahoma, and because this was the time of most pronounced deformation of the mountain area and adjacent Ardmore basin, the movement may appropriately be termed the Arbuckle orogeny. Epirogenic movement is indicated by the unconformity at the

base of the Virgil series throughout the northern Mid-Continent field and by the abundant clastic deposits of the lower Virgil. Similar conditions are suggested but not established in various other areas.

Pre-Big Blue diastrophism.—The boundary between the uppermost Pennsylvanian (Virgil series) and overlying beds in the northern Mid-Continent region that have been classed as Lower Permian (Big Blue series), has been placed at different stratigraphic horizons by various previous workers. The selected boundaries have been located at contacts that are entirely conformable. The writer's recent field studies in Kansas, Nebraska, and Oklahoma have brought to light evidence of the occurrence of a disconformity not far below the top of the Pennsylvanian as formerly defined, and this break, which is followed in places by thick sandstone and by conglomerate, is now reckoned as the proper base of the Big Blue series. In most places the boundary belongs just above the Brownville limestone, but locally the unconformity cuts downward to the Dover limestone, 100 feet or more below the Brownville. The beds above and below the break are entirely parallel, and although there are differences in lithologic character and in faunas that readily distinguish the Virgil and Big Blue strata, broadly considered, the unconformity is very inconspicuous.

Sandstones and sandy shales in the lower part of the Sand Creek formation of northern Oklahoma are regarded as basal deposits of the Big Blue series. The unconformity that forms the lower boundary of the series occurs in most places a little above the horizon of the Grayhorse limestone, which is traceable southward almost to the border of the Arbuckle uplift. In southern Oklahoma most of the Stratford and the partly contemporaneous Konawa beds are interpreted as equivalent to the lower part of the Big Blue series. Definite physical evidence of unconformity near the base of the Stratford and Konawa is now lacking, however.

Fusulinids and other fossils from the upper part of the Cisco group of north-central Texas appear definitely to indicate that at least 500 feet of beds (Moran and Putnam formations) formerly regarded as Upper Pennsylvanian are equivalent to part of the Big Blue series of the northern Mid-Continent. The Geological Survey of Texas has accordingly revised the definition of the Cisco group to exclude the Moran and Putnam beds, the boundary between Pennsylvanian and Permian being tentatively located at the base of the Moran formation (36, p. 140). The beginning of Big Blue fusulinids, however, appears to occur in the upper part of the Harpersville formation, slightly below the Saddle Creek limestone (33). This horizon

is 200 to 250 feet below the base of the Moran formation. There are lenticular sandstones and red beds in the middle part of the Harpersville that may represent initial clastic deposits of the Big Blue series, but an unconformity at this horizon is not known. Nevertheless, it is here suggested that the boundary between beds correlated respectively with the Virgil and Big Blue series be drawn tentatively near the middle of the Harpersville formation as that unit is now defined.

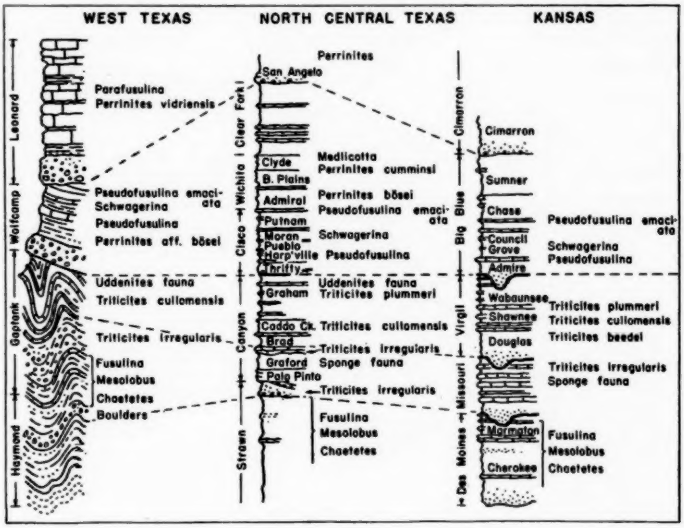


FIG. 13.—Diagrammatic sections of Pennsylvanian and Permian rocks in Texas and Kansas, showing major stratigraphic divisions and distribution of certain fossils.

In Trans-Pecos Texas the Wolfcamp formation is definitely recognizable on the basis of distinctive fossils as equivalent to part of the Big Blue series (20, 21). The Wolfcamp rests disconformably on the *Uddenites*-bearing beds of the upper Gaptank (Virgil age) in the eastern part of the Glass Mountains, but northwest of Marathon where the Gaptank strata are strongly folded and faulted, the Wolfcamp lies on the truncated edges of these beds with strong angular unconformity. In places there are some scores of feet of coarse conglomerate at the base of the Wolfcamp formation. It is very clear that the profound deformation that affected the Marathon geosyncline involves strata classed as Gaptank and that the orogeny occurred in pre-

Wolfcamp time. The folded and faulted beds below the unconformity contain Virgil fossils (23). This disturbance, called the *Marathon orogeny*, is considered to belong to post-Virgil pre-Big Blue time and to correspond in time, therefore, to the break observed elsewhere between these series.

The Sierra Diablo, the Hueco Mountains, and other parts of western Texas, as well as numerous places in New Mexico, show rather strikingly the unconformity at the base of the beds (classed as lowermost Permian) that are equivalent in age to the Wolfcamp and the Big Blue series (21). The subjacent rocks range in age from Upper Pennsylvanian to pre-Cambrian. In many places the unconformity is distinctly angular, there are prominent basal conglomerates locally, and there is a widespread overlap of the strata of Big Blue age.

Formations that, with definiteness or with question, correspond in age to the Big Blue series are widely distributed in the western United States. In many places, as in western Texas, there is a clearly marked break at the base of these "Permian" beds, but elsewhere the stratigraphic relations are not clearly determined. Limitations of knowledge and of space make it appear desirable to omit an attempt to survey evidences in this region.

In the eastern United States, rocks of Big Blue age are restricted to the northern part of the Appalachian district, in southwestern Pennsylvania and neighboring parts of adjoining states, and possibly in New England and eastern Canada. The presence of *Callipteris conferta* and other plants in the Dunkard that correspond to plants known in the Big Blue is sufficient basis for correlation, and this has furnished the chief ground for classifying these rocks as Permian. There is no doubt as to the approximate equivalence of these deposits with the Lower Rotliegende and other strata of Europe that have been similarly classed as Lower Permian, but there may be question as to the propriety of including any of the rocks of this age in the Permian. The boundary between beds that correspond in age respectively to the Virgil and Big Blue series in the Appalachian region is not known, but it is probably not far from the contact between the Monongahela and Dunkard groups.

This brief survey, together with consideration of paleontologic evidence, indicates that there is good basis for separation of the Big Blue series and equivalent deposits from underlying rocks. The boundary is not marked by clearly defined physical evidences in most places, however. The western Texas region furnishes the most definite physical indication of an important break in this part of the column, and it appears that the Marathon orogeny belongs to post-

Virgil pre-Big Blue time. Epirogenic movement, as indicated by the widespread unconformity that is definitely recognizable at the base of the rocks of Big Blue age in many places and less definitely in others, appears to have affected parts of the continent.

Pre-Leonard diastrophism.—The Leonard formation of the Glass Mountains in western Texas and overlying beds to the top of the Capitan limestone comprise a conformable succession of fossiliferous strata which, with the possible inclusion of adjacent lower and higher beds, is probably the best section of Permian in North America (20, 21). The occurrence of some crustal deformation in the west Texas region in post-Wolfcamp pre-Leonard time is shown by the angular unconformity at the base of the Leonard formation. There are considerable thicknesses of conglomerate just above this unconformity in places, but the pre-Leonard beds were not strongly deformed. Elsewhere in western Texas this break is not so clearly defined. In the Guadalupe Mountains about 500 feet of conglomerates that are apparently equivalent to the lower Leonard are reported in a core test hole above limestone and shale that probably represent the Wolfcamp (21, p. 766). Correlation of subdivisions of the Permian strata in the Sierra Diablo and Hueco mountains is not certain, but no break is recognized between beds probably equivalent to the Leonard and those containing Wolfcamp fossils.

The Leonard-to-Capitan section of western Texas corresponds in geologic age to the very widespread marine submergence of the western United States that is represented by the San Andres, Kaibab, Phosphoria, and other formations. In many places these formations rest unconformably on the underlying rocks. Correlation of the Leonard-to-Capitan beds with stratigraphic units of north-central Texas and more northerly parts of the Mid-Continent region is much too indefinite as yet to permit reliable conclusions as to the time equivalence or lack of equivalence of certain unconformities. The most significant, if not the only widely traceable break in the part of the north Texas section that lies above beds of undoubted Big Blue age, is the disconformity at the base of the San Angelo conglomerate. A few hundred feet above this, in dolomitic beds of the Blaine formation, occurrence of *Perrinites hilli*, which is exceedingly close to *P. vidriensis* of the Leonard formation, has been cited (19, p. 924) as proof of the Leonard age of the Blaine. There is no indication of important interruption of sedimentation in the Wichita or Clear Fork groups that underlie the San Angelo conglomerate, and there appears to be no satisfactory paleontologic basis for the conclusion that all of these pre-San Angelo beds may not be regarded as corresponding to the

Big Blue series. The vertebrate faunas of the Wichita and Clear Fork are closely linked with those from underlying beds, whereas notable differences are reported to distinguish vertebrates from the Double Mountain group which begins with the San Angelo (31). Among the invertebrates, presence of *Pseudofusulina* and *Schwagerina* in the Wichita beds and absence of *Parafusulina* so far as known below the Double Mountain, correspond to distribution of these fusulinids in the Glass Mountains section where the first two genera named are common in the Wolfcamp and the last is a characteristic form in the Leonard. *Perrinites* and *Medlicottia* are both recorded from the Wichita-Clear Fork and *Perrinites* occurs in the Big Blue rocks of Kansas, but these ammonites appear to be somewhat more primitive than those of the Leonard formation. This evidence is not, however, conclusive.

The San Angelo conglomerate is correlated with the Duncan sandstone in southern and west-central Oklahoma (36, p. 178). This sandstone lies near the base of the Cimarron Red-beds section and is thought to be equivalent to part of the Harper sandstone in Kansas. An unconformity appears to be present beneath these sandy deposits at a number of places, but it is not a clearly evident feature. There is no doubt, however, as to existence of an important angular unconformity at the base of the "red cave" along the buried axis of the Amarillo Mountains in the Texas Panhandle region and considerable overlap of red beds that are correlated with the Cimarron of Kansas and Oklahoma (12). Thus there is some suggestion that an important plane of stratigraphic cleavage should be recognized between the Cimarron and older beds, and between the Double Mountain and older beds. If this is true and if the suggested breaks in the northern and southern areas correspond, it is evident that the Wichita-Clear Fork section of north Texas (including some beds formerly classed as upper Cisco) is considerably thicker than the Big Blue series in Kansas, but it is equally clear that the lithologic features of the upper and lower parts of the Wichita-Clear Fork resemble respectively the upper and lower parts of the Big Blue series.

No rocks of Leonard-to-Capitan age are known in the eastern part of the United States. It is very possible, however, that the profound deformation that yielded the chief structural features of the Appalachian Mountain belt belongs to post-Big Blue pre-Leonard time. The basis for this suggestion includes, first, the evidence that the time of mountain-building was later than Dunkard, and second, the probability that this diastrophism corresponds to the Saalian disturbance recognized in western Europe. Remnant portions of the Dunkard beds

lie too far west of the belt of strong folding to permit conclusion on the basis of structural features that the orogeny was post-Dunkard, but it appears that if the mountains had been uplifted in pre-Dunkard or during Dunkard time there would be rather definite indication of this in the presence of coarse sediments derived from uplifted areas to the east. The Saalian disturbance, as noted in the early part of this paper, divides the earliest part (Lower Rotliegende) of the so-called Permian in Europe from succeeding parts, and there is no other time of diastrophism yet defined in the Late Paleozoic excepting, perhaps, the weak Pfälzian movements at the close of Permian time. There is possibility that the *Appalachian revolution* may have occurred considerably later than the time of the Saalian disturbance in Europe, since the next younger rocks in the folded region are Late Triassic. Altogether, it seems most likely that the Appalachian folding may be assigned to Saalian time.

Pre-Triassic diastrophism.—Rocks of Triassic age are separated from underlying beds in most parts of North America by an unconformity, but in some cases the break is not very conspicuous and there is doubt as to whether certain beds in some sections should be classed as Upper Permian or Lower Triassic. If exception is made of the Appalachian orogeny, concerning which it appears possible to say only that the deformation occurred between Dunkard (Big Blue) and Newark (Upper Triassic) time, there is no known evidence of post-Permian pre-Triassic folding in North America. The unconformities observed at the base of Triassic deposits indicate at most only epirogenic movements.

The Bissett conglomerate, which appears in the Glass Mountains region of western Texas, rests unconformably on Upper Permian limestone (Capitan). It attains a thickness of 750 feet and contains vertebrate remains tentatively identified as Triassic, plants that appear partly of Paleozoic and partly of Mesozoic aspect, and invertebrates (20, 21, p. 738). Some geologists consider that not only the Bissett but red beds and gypsum that are currently classed as uppermost Permian are more probably Lower Triassic. Throughout most of western Texas and New Mexico, Upper Triassic (Dockum) beds rest unconformably on the Permian, or on red beds of debated age.

There is a clearly evident disconformity in the Colorado Plateau province at the base of the Lower Triassic (Moenkopi) beds, the subjacent rocks being Upper Permian limestone (Kaibab), shale, or sandstone. Similar relations are observed between the variously named formations of probable Upper Permian and Lower Triassic age in Nevada, northern Utah, Idaho, Wyoming and Colorado. The beds

above and below the presumed boundary consist mainly of red beds, and it is evident from this similarity in the nature of deposits and from the lack of conspicuous character of the boundary betwen them that no great change occurred in this region during latest Paleozoic and earliest Mesozoic time.

CORRELATION OF EUROPEAN AND AMERICAN LATE PALEOZOIC CRUSTAL MOVEMENTS

Comparison of the European and American record of crustal movements of Late Paleozoic time calls primarily for correlation of stratigraphic units of the two continents, and this should be as precise and detailed as possible. It is evident, however, that even moderately complete consideration of paleontologic and other testimony bearing on such correlation would extend this paper far beyond reasonable limits. I shall, therefore, offer the shortest possible summary of pertinent data, leaving details for development elsewhere.

Bretonian and Acadian orogenies.—Since the term Bretonian in Europe is extended to cover folding movements that began well before the close of Devonian time, it seems reasonable to conclude that the Bretonian and Acadian orogenies are at least partly equivalent. Three distinct stages or "phases" of Bretonian movements are now recognized (Marsian, Nassauan, Selkian), of which the last probably corresponds in time to the widespread break at the base of the American Kinderhook beds.

The Kinderhook series contains *Aganides rotatorius*, *Protocanites*, *Muensteroceras*, *Pericyclus* and other ammonoids that distinguish the Tournaisian. They represent the *Protocanites* and *Pericyclus* zones of Schmidt (34). The Tournaisian also contains numerous genera of the highly developed class of crinoids called Camerata, which occur very abundantly in the Osage beds of the central United States. The camerates suddenly disappear almost completely above the Tournaisian and above the Osage beds. The position of the boundary between Kinderhook and Osage is not now identified in the Tournaisian, and it is probable that this has only minor significance in American Carboniferous history. Time equivalents of the Osage deposits are believed to extend no higher than the *Caninia* zone of the British Avonian or the uppermost Tournaisian rocks of continental Europe.

Pre-Viséan and pre-St. Louis movements.—No orogenic crustal movements of middle Lower Carboniferous or Mississippian time are indicated in Europe or North America, but in both continents there is evidence of some epirogenic movements and of attendant lithologic and faunal changes. The Viséan deposits are characterized by several

types of corals, including *Lithostrotion*, brachiopods, and appearance of *Goniatites* and other ammonoids that are more advanced than Tournaisian forms. The St. Louis limestone is characterized by presence of *Lithostrotion*, and it is probable that the St. Louis and Ste. Genevieve beds of America correspond to the *Seminula* and lower *Dibunophyllum* zones of the British Avonian (which includes the *Beyrichoceras* zone of Bisat) (5, 7), and to most of the Viséan rocks as currently defined in northwestern Europe.

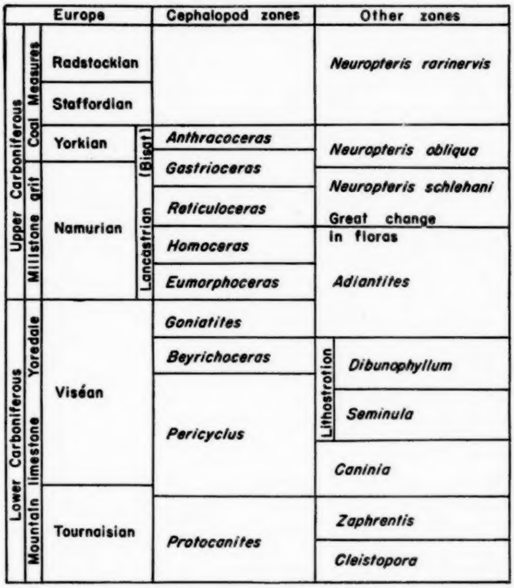


FIG. 14.—Diagram showing main stratigraphic divisions of Carboniferous rocks in Europe and fossil zones.

Sudetian orogeny and pre-Chester movement.—The important Sudetian folding is dated as later than Culm, that is, late Viséan or post-Viséan, and it preceded deposition of clastic beds that are classified as lower Namurian. The upper Viséan and the Namurian rocks of Europe have been minutely zoned on the basis of ammonoids, and plant fossils in different regions have been carefully studied. At the top of the Viséan is the *Goniatites* zone, containing *Goniatites crenistria*, *G. newsomi*, *G. subcircularis*, *Sagittoceras meslerianum*, all

of which occur in Chester deposits of America, and numerous related forms. With this zone the Bowland shale and associated grits of the Pendleside and Yoredale series in England begin. Conformably above the *Goniatites* zone comes the *Eumorphoceras* zone which is now defined as the lowermost part of the Namurian, or basal Upper Carboniferous. The *Eumorphoceras* zone contains *Eumorphoceras bisulcatum* which was originally described from the Caney shale, Chester, of southern Oklahoma. Next higher comes the *Homoceras* zone with another group of ammonoids, among which is *Homoceras subglobosum*, so similar to *H. richardsonianum* of the Caney shale that the two may be identical. Evidence is thus conclusive that the Chester series in North America corresponds at least to the uppermost zone of the Viséan and the lower part of the Namurian. It is interesting and probably significant as a factor in correlation that the beginning of definitely rhythmic or cyclic sedimentation occurs in the Chester rocks of the United States and in the Pendleside-Yoredale series of Great Britain, which on fossil evidence are regarded as equivalent.

The boundary between Lower and Upper Carboniferous, which in Europe is placed between Viséan and Namurian, falls within the Chester, and probably toward the lower part of the Chester. There is a recently expressed tendency among some British geologists (17) to lower the Viséan-Namurian boundary to the base of the *Goniatites* zone, which would approximately correspond to the base of the Chester series, and this seems a desirable change. But it is clear that the European Upper Carboniferous is not at all synonymous with Pennsylvanian as defined in America. We may conclude for the present that the Sudetian orogeny of Europe, occurring between the European Lower and Upper Carboniferous, corresponds to the break at the base of the Chester series in North America.

Erzgebirgian orogeny and pre-Morrow movements.—It has been noted that in Europe there are evidences of crustal deformation within the epoch called Namurian, and this is shown by angular unconformities, by the spreading of coarse grits, and by a widely recognized important "break" in floras. These conditions may be compared to changes that in North America introduce Pennsylvanian time (Morrow, including lower and middle Pottsville). Here there was strong uplift of borderlands that resulted in deposition of thick coarse clastic formations in geosynclinal areas, and the changes in floras and marine invertebrates appear to correspond to those observed in Europe. The Chester floras are not well known, but according to David White the presence of *Cardiopteris* referable to *C. polymorpha* (Goeppert), *Sphenopteris* of a type that appears ancestral to the

important European guide fossil *S. hoeninghausi*, and other species may be compared most closely to fossil plants of the Waldenburg, Ostrau, and other European early Namurian deposits. On the other hand, the fairly large, well preserved flora of beds of Morrow age includes *Neuropteris smithii* belonging to the *N. schlehani* group, *Sphenopteris hoeninghausi*, and *Zeilleria*, which among other forms distinguish the upper Namurian and lower part of the Westphalian. Among ammonoids, the Morrow contains *Reticuloceras* (in the Marble Falls limestone of Texas, reported to me by F. B. Plummer and Gayle Scott) which is the guide fossil of the *Reticuloceras* zone in the upper Namurian of England (Millstone grit) and on the continent. The Morrow beds also yield several forms of typical *Gastrioceras*, including *G. listeri*, which distinguish the *Gastrioceras* zone, next above the *Reticuloceras* zone in Europe. The *Gastrioceras* zone includes beds classified at the summit of the Namurian and in the lower part of the Westphalian.

Wichita orogeny.—Deposits of Des Moines age are clearly separable by a sharp break in various parts of North America from underlying Pennsylvanian beds, and in parts of the Mid-Continent region there is distinct evidence of pre-Des Moines folding and faulting. Is there any comparable break in the European Carboniferous succession?

The Des Moines strata are especially characterized paleontologically by the presence of common *Mesolobus*, distinctive forms of *Marginifera*, *Spirifer* and other brachiopods, *Fusulina*, *Fusulinella* and other primitive fusulinids, *Chaetetes*, *Prismopora*, and among the ammonoids by appearance along with *Gastrioceras* of various species of *Schistoceras*, *Neodimorphoceras* and *Gonioloboceras*. Unfortunately these marine organisms are lacking almost altogether in western Europe. An ammonoid *Homoceratoides jacksoni* described from the "Middle Coal Measures" (Staffordian) of England and equivalent to upper middle Westphalian rocks of northwestern Europe, is, however, represented by a practically identical form in the upper Des Moines (Marmaton) beds of Missouri (6). The Des Moines fusulinids and other invertebrates are also represented in the Moscovian rocks of eastern Europe, which is correlated with Westphalian.

The Des Moines series and equivalent beds of the Appalachian region (upper Pottsville, Alleghany) contain a richly varied flora, and this contains a number of plants that are characteristic of the middle and upper Westphalian (zones B and C) of Europe. On the basis of plants, the Des Moines beds may be correlated rather definitely with the upper Yorkian, Staffordian, and part (probably all)

of the Radstockian of England. This conclusion is based both on direct comparisons and on correlation of the American and British sections with the Donetz Basin section of Russia that, like the Kansas-Missouri section, contains an alternating succession of marine invertebrate and land-plant zones. The highest occurrence of *Neuropteris heterophylla* and *Linopteris münsteri* near the middle of the Cherokee shale and in division C_2^6 of the uppermost Moscovian of the Donetz Basin, followed in Russia by the *Anthracomya tenuis* and *A. pruvosti* zone, indicates (1) that the boundary between Moscovian and Uralian belongs well below the top of the American Des Moines, and (2) that the Staffordian is clearly equivalent to part of the Des Moines. Types of *Sphenophyllum* and *Neuropteris* that are useful guide fossils, occurring in the Missouri and basal Virgil beds of the central United States, are found to compare with European plants belonging higher than Radstockian, and therefore furnish corroboration of other correlations.

It appears from this study that the main body of Westphalian deposits in Europe corresponds to the Des Moines series of North America, but at present there is no definite evidence in Europe of discordance or "break" between these and older deposits.

Asturian orogeny and pre-Missouri movements.—The Asturian crustal deformation is of major importance in parts of northwestern Europe. Sedimentation in various Westphalian basins ceased and the deposits in these basins were folded and faulted. Igneous intrusions affected some regions. This time of unrest in Europe is tentatively correlated with the withdrawal of Des Moines seas and widespread interruption of sedimentation that preceded Missouri time in North America. Although this is one of the most clearly defined stratigraphic boundaries in the American Pennsylvanian, there is no indication of orogenic movements in any part of this continent.

The Missouri series is characterized paleontologically by disappearance of distinctive Des Moines invertebrates, such as the primitive fusulinids, *Mesolobus*, and other forms, and on the other hand by appearance of true *Triticites*, by the common presence of *Chonetina*, *Enteletes*, new forms of *Marginifera* and other shells. The Missouri beds may be known as the zone of *Triticites irregularis*. Among cephalopods of the Missouri beds are *Gonioloboceras*, *Schistoceras*, *Prouddenites*, *Marathonites*, *Shumardites* and *Gastrioceras*. The flora of the Missouri series is characterized by disappearance of *Lepidodendron* and sphenophylls of the *Sphenophyllum majus* and *S. emarginatum* types, in place of which an anisophyllous form comparable to *S. oblongifolium* is developed. There is indication of gradual

change to a drier type of flora in the latter part of the Missouri epoch, shown by widespread and abundant *Cordaites* and by occurrence of the interesting *Walchia* flora discovered at the top of the series near Garnett, Kansas (29).

It is possible that beds of Missouri age are less well represented in Europe than in North America. Most probable equivalents of the Missouri are certain deposits at the base of Late Carboniferous basins in France and Germany where beds of Stephanian age are underlain by beds now classed as pre-Stephanian (or latest Westphalian), these latter resting with strong unconformity on older rocks. In southeastern Germany and Bohemia the so-called uppermost Westphalian consists of coarse clastic deposits that rest discordantly on older Westphalian, and these clastics may represent the Missouri. Jongmans and Gothan (18) have recently published the conclusion that all of the American Upper Pennsylvanian rocks are Westphalian in age, but they also conclude that the late Missouri flora from Garnett is Lower Permian. There are strongest reasons for believing that both of these ideas are erroneous.

Arbuckle orogeny.—The deformation in part of the central United States termed the Arbuckle orogeny, and the unconformity at the base of the Virgil series, are not certainly recognizable in the European record. It seems more probable that the Asturian orogeny is pre-Missouri than that it corresponds in time to the Arbuckle folding. The Virgil series is chiefly distinguished by abundance of typical *Triticites* among the fusulinids, most of the other invertebrates being closely related to Missouri forms. Unfortunately the succession of fusulinid zones in the Russian Carboniferous is too little known to give much aid in correlation, and this group of fossils, or indeed, all marine invertebrates are lacking in the Late Carboniferous of northwestern Europe. The Virgil plants, however, include numerous species of ferns, sphenophylls, and some lepidophytes that permit correlation with the Stephanian. Among the more significant types for intercontinental correlation are species of *Odontopteris*, *Sphenophyllum oblongifolium*, *Neuropteris gleichenioides*, *Pecopteris feminaeformis*, *P. leptophylla*, *Sigillaria beardi*, and others. The genus *Callipteris*, but not the species *C. conferta*, which is used as a guide fossil of the Autunian or lower Rotliegende, classed as Lower Permian, occurs in upper beds of the Virgil series in Kansas.

Marathon orogeny.—If the strong deformation in the west Texas region is correctly correlated in time with the rather obscure disconformity at the base of the Big Blue series in the northern Mid-Continent region, this may be reckoned as physical interruption be-

tween Late Carboniferous and Early Permian as these divisions are currently defined in western Europe and North America. The Big Blue series and equivalent beds are characterized faunally by the presence of robust, highly developed *Triticites* and by appearance of the genera *Schwagerina* and *Pseudofusulina* among the fusulinids, by such advanced genera as *Artinskia* and *Perrinites* among the ammonoids, and by other changes in the invertebrates. Some of these may be compared with Artinsk marine fossils in the Russian section. Among plants, the Big Blue beds contain numerous typical *Callipteris conferta*, *Taeniopteris coriacea*, *Sphenophyllum fontainianum*, *S. obovatum*, *Odontopteris*, *Glenopteris* and *Walchia*. There is little question of age equivalence of these beds with Dunkard deposits in the Appalachian region and lower Rotliegende or Autunian deposits in western Europe. The European beds named are reported to lie concordantly on upper Stephanian strata, and it is therefore evident that no significant crustal movements of post-Stephanian pre-Autunian date occur.

Saalian orogeny and Appalachian orogeny.—As previously indicated, the Saalian deformation, that in Europe is recognized between early and late Rotliegende time, is much less important than some of the preceding orogenies. There is no definite evidence that it corresponds to the Appalachian orogeny which strongly affected eastern North America and probably the Ouachita geosyncline in post-Dunkard (Big Blue, lower Rotliegende) time, but this seems probable. On the other hand, since it appears that other Late Paleozoic crustal movements are marked by orogeny in one continental area and only by epirogeny in the other, it is possible that the Appalachian orogeny is wholly later than the Saalian.

The Leonard and younger formations of western Texas are characterized by presence of complexly sutured ammonoids, including *Waagenoceras*, *Medlicottia*, *Prothalassoceras*, *Perrinites*, *Adrianites*, *Stacheoceras* and others, by specialized brachiopods such as *Aulosteges*, *Lyttonia* and *Prorichtofenia*, and by the fusulinid genera *Parafusulina* and *Polydiexodina*. These beds may be correlated with Saxonian and Thuringian (Zechstein) rocks of Europe, which in various places overlie Carboniferous or pre-Carboniferous rocks with profound unconformity. *Gigantopteris* and sphenophylls, with other plants, support this correlation.

Pfälzian movement.—Very weakly defined crustal movements of post-Zechstein date are reported in parts of Europe, but in many places the Upper Permian and Triassic beds are entirely concordant and there is even difficulty in determining a boundary. Generally

similar conditions prevail in North America, for where so-called Late Permian and Early Triassic deposits are both present they are concordant in structure, in many cases they are similar in lithologic character, and there may be difficulty in drawing a boundary between them. Altogether, there are physical and biologic bases for doubt as to suitability of existing stratigraphic and chronologic classification of the Permian and Triassic, and of the boundary between Paleozoic and Mesozoic, but these will not be discussed here.

CONCLUSION

The evidences that have been reviewed, very inadequately it must be admitted, seem sufficient to support the conclusion that diastrophic movements of importance in one continent are probably expressed by contemporaneous effects in other continents, and that this interrelationship is a basic element in intercontinental stratigraphic correlation. A summary of the suggested correlations between European and American crustal movements of Late Paleozoic time is given in the accompanying table.

TABLE II

CORRELATION OF EUROPEAN AND AMERICAN CRUSTAL MOVEMENTS OF LATE PALEOZOIC TIME

Europe	*North America*
TRIASSIC	TRIASSIC
Pfälzian orogeny	*Epirogenic movement*
PERMIAN	PERMIAN
Thuringian Saxonian	Leonard-Capitan
Saalian orogeny	*Appalachian orogeny*
Autunian	Big Blue
Epirogenic movement (?)	*Marathon orogeny*
UPPER CARBONIFEROUS	PENNSYLVANIAN
Stephanian	Virgil
Epirogenic movement (?)	*Arbuckle orogeny*
Westphalian, zone D	Missouri
Asturian orogeny	*Epirogenic movement*
Westphalian, zones B, C	Des Moines
Epirogenic movement (?)	*Wichita orogeny*
Westphalian, zone A Upper Namurian	Morrow
Erzgebirgian orogeny	*Epirogenic movement*
	MISSISSIPPIAN
Lower Namurian	Chester
Sudetian orogeny	*Epirogenic movement*
LOWER CARBONIFEROUS	
Viséan	Meramec
Epirogenic movement	*Epirogenic movement* (?)
Tournaisian and Etroeungtian	Osage and Kinderhook
Bretonian orogeny	*Epirogenic movement*
DEVONIAN	DEVONIAN

In proportion as the geologic dates of diastrophism in specific areas can be determined with precision and to the extent that paleontologic or other evidence can be developed for close comparison of the record of sedimentation and interruption of sedimentation in different areas, it will be possible to test the principles that are involved and to apply them to more accurate interpretation of geologic history. Present knowledge is far too incomplete to establish the thesis that has been presented, but it is believed this line of study offers promise of useful future results.

Acknowledgments.—The writer wishes to acknowledge the aid of his colleagues, M. K. Elias, who has contributed results of careful studies of fossil plants, and N. D. Newell, who has furnished certain information concerning invertebrate fossils and results of field observations in Oklahoma. Certain data relating to the Pennsylvanian rocks of Illinois have been drawn from information kindly furnished by J. Marvin Weller and H. R. Wanless, and similarly on New Brunswick and Nova Scotia by W. A. Bell.

REFERENCES

1. M. B. Arick, "Occurrence of Strata of Bend Age in Sierra Diablo, Culberson County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16 (1932), pp. 484–87.

2. C. L. Baker, "Erratics and Arkoses in the Middle Pennsylvanian Haymond Formation of the Marathon Area, Trans-Pecos Texas," *Jour. Geol.*, Vol. 40 (1932), pp. 577–603.

3. W. A. Bell, "The Mississippian Formations of the Horton-Windsor District, Nova Scotia," *Amer. Jour. Sci.*, (5), Vol. 1 (1921), pp. 153–73.

4. Paul Bertrand, "L'échelle stratigraphique du terrain houiller de la Sarre et de la Lorraine," Congrès de Stratigraphie Carbonifère Heerlen, 1927, *Comptes rendus* (1927), pp. 83–92.

5. W. G. Bisat, "The Carboniferous Goniatites of the North of England and Their Zones," *Proc. Yorkshire Geol. Soc.*, Vol. 20 (1924), pp. 40–124.

6. ———, "On the Occurrence of a British Coal Measure Goniatite in Missouri, U.S.A.," *Proc. Yorkshire Geol. Soc.*, Vol. 22, Pt. 1, pp. 1–8.

7. ———, "The Carboniferous Goniatite Zones of England and Their Continental Equivalents," Congrès de Stratigraphie Carbonifère, Heerlen, 1927, *Comptes rendus* (1927), pp. 117–30.

8. W. H. Bucher, *The Deformation of the Earth's Crust*, Princeton, Princeton Press (1933), 518 pp.

9. R. T. Chamberlin, "Periodicity of Paleozoic Orogenic Movements," *Jour. Geol.*, Vol. 22 (1914), pp. 315–45.

10. T. C. Chamberlin, "Diastrophism as the Ultimate Basis of Correlation," *Jour. Geol.*, Vol. 17 (1909), pp. 685–93.

11. M. G. Cheney, "Stratigraphic and Structural Studies in North-Central Texas," *Texas Univ. Bull. 2913* (1929), 29 pp.

12. Victor Cotner and H. E. Crum, "Geology and Occurrence of Natural Gas in the Amarillo District, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17 (1933), pp. 877–906.

13. E. J. Garwood, "Zonal Divisions of the Carboniferous System," *Brit. Assn. Adv. Sci. Rept. for 1895* (Ipswich) (1895), pp. 696 ff.

14. ———, "The Lower Carboniferous Succession in the Northwest of England," *Quart. Jour. Geol. Soc.*, Vol. 48 (1912), pp. 449–586.

15. ———, "The Faunal Succession in the Lower Carboniferous Rocks of Westmoreland and North Lancashire," *Proc. Geol. Assoc.*, Vol. 27 (1916), pp. 1–48.

16. W. Gropp, "Beziehungen zwischen dem Oberschlesischen und dem Westfälischen Karbon," *Glückauf Berg. u. Hütten., Zeitschr.*, Vol. 69 (1933), No. 36, pp. 823–26.

17. R. G. S. Hudson and J. S. Turner, "Correlation of Dinantian and Namurian in Western Europe," *Leeds Philos. and Lit. Soc., Proc. Sci. Sec.*, Vol. 2 (1933), Pt. 10, pp. 467–82.

18. W. J. Jongmans and W. Gothan, "Florenfolge und Vergleichende Stratigrafie des Karbons der Östlichen Staaten Nord-Amerikas, Vergleich mit West-Europa," *Geol. Bur., Heerlen*, Jaarverslag over 1933 (1935), pp. 17–44.

19. P. B. King and R. E. King, "Stratigraphy of the Outcropping Carboniferous and Permian Rocks of Trans-Pecos Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13 (1929), pp. 907–26.

20. ———, "The Geology of the Glass Mountains, Texas," *Texas Univ. Bull. 3038* (1931), 167 pp.

21. ———, "Permian Stratigraphy of Trans-Pecos Texas," *Bull. Geol. Soc. Amer.*, Vol. 45 (1934), pp. 697–798.

22. Murray Macgregor, "The Scottish Millstone Grit and Its Position in the Zonal Succession," *Great Britain Geol. Survey Summ. Progress for 1933* (1934), Pt. 2, pp. 1–7.

23. A. K. Miller, "A New Ammonoid Fauna of Late Paleozoic Age from Western Texas," *Jour. Paleont.*, Vol. 4 (1930), pp. 383–412.

24. ———, "A Pennsylvanian Cephalopod Fauna from South-Central New Mexico," *Jour. Paleont.*, Vol. 6 (1932), pp. 59–93.

25. H. D. Miser, "Llanoria, the Paleozoic Land Area in Louisiana and Eastern Texas," *Amer. Jour. Sci.*, (5), Vol. 2 (1921), pp. 61–89.

26. ———, "Structure of the Ouachita Mountains of Oklahoma and Arkansas," *Oklahoma Geol. Survey Bull. 50* (1929), 112 pp.

27. ——— and E. H. Sellards, "Pre-Cretaceous Rocks Found in Wells in the Gulf Coastal Plain South of the Ouachita Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 801–18.

28. Raymond C. Moore, "Early Mississippian Formations of Missouri," *Missouri Bur. Geol. and Mines* (2), Vol. 21 (1928), 283 pp.

29. ———, M. K. Elias, and N. D. Newell, "A 'Permian' Flora from Pennsylvanian Rocks of Kansas," *Jour. Geol.* (in press).

30. F. B. Plummer and R. C. Moore, "Stratigraphy of the Pennsylvanian Formations of North-Central Texas," *Texas Univ. Bull. 2132* (1921), 237 pp.

31. A. S. Romer, "Vertebrate Faunal Horizons in the Texas Permo-Carboniferous Red Beds," *Texas Univ. Bull. 2801* (1928), pp. 67–108.

32. G. Ross, "An Unconformity of Millstone Grit Age in the Douglas Coal Field of Lanarkshire," *Great Britain Geol. Survey Summ. Progress for 1930* (1931), Pt. 2, pp. 39–43.

33. Robert Roth, "New Information on the Base of the Permian in North-Central Texas," *Jour. Paleont.*, Vol. 5 (1931), p. 295.

34. H. Schmidt, "Die Karbonischen Goniatiten Deutschlands," *Preuss. Geol. Landes. Jahrb. 1924*, Bd. 45 (1925), pp. 489 ff.

35. Charles Schuchert, "Paleogeography of North America," *Bull. Geol. Soc. America*, Vol. 20 (1910), pp. 427–606.

36. E. H. Sellards, "The Pre-Paleozoic and Paleozoic Systems in Texas," *Texas Univ. Bull. 3232* (1932), pp. 15–238.

37. Hans Stille, *Grundfrage der Vergleichende Tektonik*, Berlin, Borntraeger (1924), 443 pp.

38. C. W. Tomlinson, "The Pennsylvanian System in the Ardmore Basin," *Oklahoma Geol. Survey Bull. 46* (1929), 79 pp.

39. E. O. Ulrich, "Revision of the Paleozoic Systems," *Bull. Geol. Soc. America*, Vol. 22 (1911), pp. 281–680.

40. S. Von Bubnoff, "Die Westfälische Sedimentation und die Asturische Phase in der Innersudetischen Mulde," *Fortschritte d. Geol. u. Pal.*, Bd. 9, Heft 29, Berlin, Borntraeger (1931), pp. 407–97.

41. M. P. White, "Some Texas Fusulinidae," *Texas Univ. Bull. 3211* (1932), 105 pp.

42. W. B. Wright, "The Millstone Grit," in *Handbook of the Geology of Great Britain*, London, Murby (1929), pp. 251–59.

DISCUSSION

P. B. King, Washington, D. C. (written discussion received, June 20, 1935): Dr. Moore's paper deals with the question of the character and extent of the various movements of later Paleozoic time. He favors the belief that individual periods of diastrophism are brief, but of wide—possibly world-wide—extent. In this belief he has the precedent of the opinion of a number of distinguished geologists.

The more recent trend taken by this theory, and that which Moore favors, is that, instead of a relatively few widespread movements, there are a great number of movements, several within a period. This fits more closely with the observed facts than the former, more general picture. However, it necessitates much closer correlation of movements than hitherto, and perhaps closer than we can now safely make. If we assume for a moment that diastrophism is not widespread after all, a number of closely spaced movements in one area could easily be confused with movements at slightly different times in another area.

In his tables, and in the text, Moore speaks of the pre-Des Moines movements as the Wichita orogeny, and the pre-Virgil movements as the Arbuckle orogeny. I suppose that these terms are taken from van der Gracht's paper, but they represent a restriction of the terms as used by van der Gracht. As originally used by this author, they applied in a more general way to groups of movements near the Mississippian-Pennsylvanian boundary, and near the Pennsylvanian-Permian boundary. These were divided into a number of "pulsations," two of which would correspond more closely to the terms as used by Moore. I believe that the terms in their original sense are more useful to geologists, and I should regret to see them more narrowly restricted.

The implied correlation of the pre-Leonard and pre-Double Mountain unconformities, and of the Wolfcamp formation with the whole of the upper Cisco, the Wichita, and the Clear Fork groups is open to question. The idea has some attractive features, but it can not be entirely reconciled to existing evidence, as enumerated below under several headings.

1. The fossils of the Wolfcamp formation, including *Schwagerina* and other fusulinids, and *Perrinites* cf. *bösei* and other ammonoids, indicate a correlation with the upper Cisco and the lower Wichita only. 2. The Wolfcamp formation is not much more than 500 feet thick, and the groups in central Texas are several thousand feet thick. 3. Mr. Plummer has expressed the opinion that the ammonoids of the Clear Fork group were most nearly similar to ammonoids in the Leonard formation. 4. The existence of *Parafusulina* in the Double Mountain group in central Texas has been implied at one place in the paper. This fossil may have been found there, but its occurrence is not known to me, and until more definite evidence is cited, both the observation and the reasoning derived from it are questionable. 5. If the pre-Leonard and pre-Double Mountain unconformities were the same, the reasoning in (1) and (2) would imply that a great amount of strata in west Texas, including equivalents of the upper Wichita group and the Clear Fork group, had been removed by erosion. Thi is conceivable if the Glass Mountains alone were involved. However, in the Sierra Diablo and other areas farther northwest in Trans-Pecos Texas, rocks with Bone Spring fossils overlie those with Hueco fossils, and these faunas may be certainly correlated with those of the Leonard and those of the Wolfcamp in the Glass

Mountains section. Diligent search in this region has revealed no break between the two formations. 6. The Wichita and Clear Fork groups are traceable by subsurface work for a long distance westward from their outcrops. It is true, however, that the gap between central Texas and the Glass Mountains has not been completely filled. From what I know of the subsurface work, there would seem to be no extensive cutting out of Wichita and Clear Fork rocks by a pre-Double Mountain unconformity on proceeding toward the Glass Mountains. Indeed, the San Angelo sandstone and conglomerate above the unconformity at the base of the Double Mountain group fades out not far west of its outcrop, and beyond that point I do not believe that the boundary between the Double Mountain and the underlying Clear Fork has been traced successfully.

The present lines of evidence thus suggest that the Double Mountain-Clear Fork contact is more likely to lie within the Leonard formation of Trans-Pecos Texas, than at its base.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), PP. 1308-1329, 9 FIGS.

GEOLOGY AND GEOPHYSICS OF SOUTHEAST FLANK OF JENNINGS DOME, ACADIA PARISH, LOUISIANA, WITH SPECIAL REFERENCE TO OVERHANG[1]

M. T. HALBOUTY[2]
Beaumont, Texas

ABSTRACT

The Jennings salt dome is one of the first domes recognized in the Gulf Coast, having been discovered in 1901. However, the salt was not encountered and cap rock wholly penetrated until after 1926, when the structure was definitely proved to be a true salt dome. Drilling exploration for the past nine years has been limited to the flanks of the dome, mainly its southeast flank. The Yount-Lee Oil Company has drilled the west, north, and southeast flanks of the dome. The southeast flank is the only one proved productive, with four wells now producing out of fourteen drilled. Geophysical as well as geological observations have indicated an overhang on the southeast flank. The productive sands on this flank are Middle Oligocene in age and are classified as high-pressure sands.

LOCATION

The Jennings salt dome is located in Acadia Parish, Louisiana, near the center of T. 9 S., R. 2 W., 7 miles northeast of the town of Jennings, and 36 miles east of the city of Lake Charles. The dome is commonly referred to as the Evangeline dome, because the small settlement of Evangeline is located in the field. The field can be reached by gravel road, Louisiana State Highway 371, leading northeast from Jennings to Iota, and also by small boat *via* Mermentau River, thence into the Bayou des Cannes. There is no railroad in the immediate vicinity of the field, the nearest being the Southern Pacific at Jennings.

HISTORY

The Jennings oil field is one of the oldest oil fields in the Gulf Coast. Barton and Goodrich[3] published a report on this field in 1926, giving a thorough description of the development to that time.

[1] Read by title before the Association at the Wichita meeting, March 23, 1935. Manuscript received, May 27, 1935. Published by permission of the Yount-Lee Oil Company, Beaumont, Texas. The writer wishes to express his appreciation to E. U. Henry, chief engineer of the Yount-Lee Oil Company, for his sincere coöperation and assistance rendered in the compiling of the geophysical data and for his many suggestions and criticisms on the subject of the paper. Without his permission and coöperation, this paper would not have been possible.

[2] Chief geologist and petroleum engineer, Yount-Lee Oil Company. Present address: geologist and petroleum engineer, Glenn H. McCarthy, Inc., Sterling Building.

[3] Donald C. Barton and R. H. Goodrich, "The Jennings Oil Field, Acadia Parish, Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 1 (January, 1926), pp. 72–92.

The first well was drilled in August, 1901, by the Jennings Oil Company and the Heywood Brothers. This well was drilled to a depth of 1,882 feet in loose sand that contained gas and oil in such quantities as to cause a blow-out, which finally caused the abandonment of the well.

In June, 1902, the first successful productive well was completed. Wells were then drilled in all directions from this producer which has subsequently been proved to be on the western edge of the center of the dome proper.

In 1906, the production for the field reached a total of 9,025,000 barrels, which is the peak production for the field to date. It steadily declined to 191,000 barrels in 1922, and subsequently production has been fluctuating from 200,000 barrels to 575,000 barrels per year. The total production per year for the field is shown in Table I.

TABLE I

JENNINGS FIELD, CRUDE OIL PRODUCTION BY YEAR IN BARRELS

1901	5,000	1919	347,000
1902	548,000	1920	232,000
1903	900,000	1921	254,000
1904	7,200,000	1922	191,000
1905	8,891,000	1923	204,000
1906	9,025,000	1924	213,000
1907	4,842,000	1925	349,319
1908	5,111,000	1926	418,720
1909	1,966,000	1927	415,240
1910	1,625,000	1928	373,900
1911	1,180,000	1929	575,150
1912	1,105,000	1930	527,834
1913	790,000	1931	254,363
1914	412,000	1932	295,441
1915	435,000	1933	387,000
1916	517,000	1934	454,000
1917	399,000		
1918	369,000	Total	50,811,967

At the time of the completion of Barton and Goodrich's[4] paper, the salt had not been penetrated and the cap rock had not been drilled through completely either on or off the dome. Since that time several wells have been drilled through the cap rock into the salt on the dome proper, and the cap rock has been thoroughly penetrated on the flanks of the dome.

To 1929 all production had been from the dome proper, with no producing wells on the flanks.

In 1928, the Yount-Lee Oil Company of Beaumont, Texas, obtained leases on the southeast, northeast, and west flanks of the dome for the purpose of obtaining deep production. The Houssiere-Latrielle

[4] Donald C. Barton and R. H. Goodrich, *op. cit.*

Oil Company's leases in Section 47 were drilled by the Young-Lee Oil Company on locations on the dome proper, and the exploration work was extended toward the southeast flank. Production was obtained from the Yount-Lee Oil Company's Houssiere-Latrielle No. 6, with an initial flow of 2,500 barrels of oil per day. The total depth for this well is 7,294 feet. Fourteen wells have been drilled on this section. The deepest is Yount-Lee Oil Company's Houssiere-Latrielle No. 9, which was drilled to 8,903 feet. These wells defined the eastern slope and edge of the dome. Total production from this lease since the completion of Houssiere-Latrielle No. 6 on June 2, 1929, to April 1, 1935, is 1,293,443 barrels. On the west flank the Yount-Lee Oil Company's Fee Sims No. 1, located 1,073 feet north and 1,146 feet west of the southeast corner of Sec. 45, T. 9 S., R. 2 W., was drilled to a depth of 7,318 feet. The hole was abandoned, with no oil showings reported. On the north and northeast flanks in Section 48, the company drilled seven deep tests on the Crowley Oil and Mineral Company's leases; the deepest test was Yount-Lee Oil Company's Crowley Oil and Mineral Company's No. 4, drilled to 8,200 feet. No production was found.

The Texas Company drilled for flank production on the south flank but with no success. The Texas Company's Rayne Heirs' No. 5, was drilled to 8,732 feet and abandoned.

At present, the Yount-Lee Oil Company is the only operator drilling for deep production on the flanks of the dome; the activity is entirely centered on the Houssiere-Latrielle lease in Section 47.

PHYSIOGRAPHY

The Jennings dome is located in the Louisiana Gulf Coastal Plain region, and the topography of the dome proper is that of a mound rising from the low lands surrounding the field. At the time of the completion of Barton and Goodrich's[5] paper, the drilling activity was centered mainly west of this mound, and the available data led them to conclude that the dome topography consisted of a

> broad, shallow, irregular basin-like depression which is drained by a brook and its ramifying branches, and of a low, irregular *hill*[6] to the east. The basin is about 1½ miles in diameter and covers a large part of the richly productive area in the center of the field as well as a much larger area of much poorer productive territory to the west.[7]

[5] *Ibid.*

[6] Italicized by Halbouty.

[7] Donald C. Barton and R. H. Goodrich, *op. cit.*, p. 75.

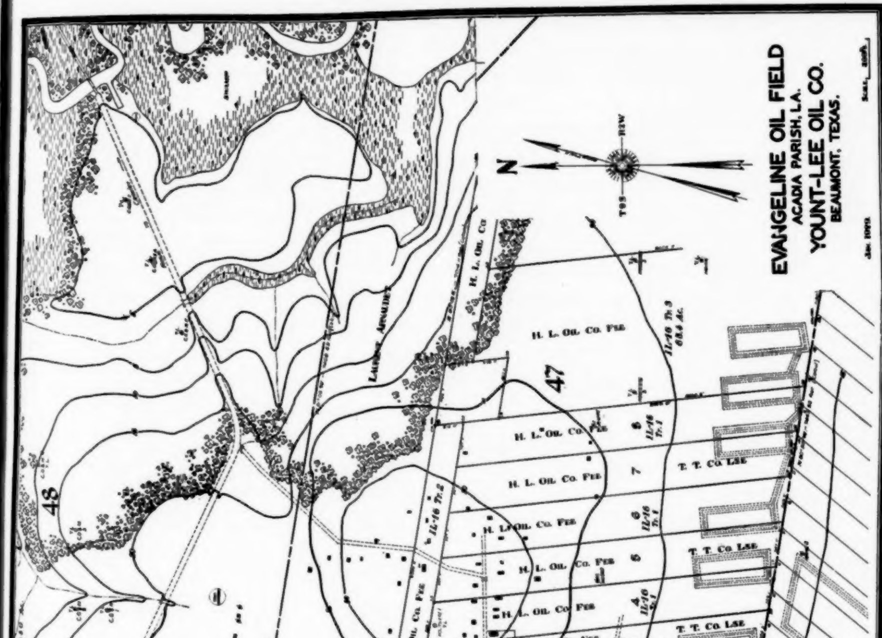


FIG. 1.—Surface contour map of Jennings salt dome ("Evangeline oil field"), showing radial drainage system from topographic "high on" top of dome. Topographic contour interval, 5 feet.

Such a topographic feature is present west of the dome topographic "high"; however, since the advent of later drilling the hill referred to in the foregoing statement has been proved by the drilling of cap rock and salt to be in the center of the dome proper. The lowest elevation above sea-level on the flanks of the dome is 5 feet, and the top of the mound consists of a knoll about 30 feet in elevation and 0.5 mile in diameter, which slopes in all directions to the surrounding plains, affecting the drainage from the mound accordingly. Figure 1 shows the topographic contours of the field, and the gradual rise to the hill is clearly shown with radial drainage downward from the hill. This topographic feature is typical of similar proved salt domes in the Gulf Coast. The depression-like basin exists west of the dome, and the discovery well is shown in the Jennings Oil Company's tract, Section 46, which led to the belief that the dome existed farther west.

The normal drainage of the area is from the north and northwest toward the southeast into the Bayou des Cannes and its attendant marshes. East of the hill along the Bayou des Cannes, the land is wooded with pine and deciduous trees. The land west of the hill is a typical Louisiana prairie.

SURFACE GEOLOGY

With the exception of a few feet of Recent alluvial deposits, the Beaumont clay is present on the surface of the field. The maximum thickness of the clay is found off the dome on the flanks, and the minimum thickness is found on top of the topographic "high." Drainage lines extending from the knoll in all directions have been and are still important factors in the erosion of the topographic "high" and the deposition of alluvial deposits in the surrounding flats. The Beaumont clays vary in thickness from 25 to 100 feet.

STRATIGRAPHY

The first definite sand and gravel beds represent the base of the Beaumont clays and the top of the Lissie formation. The Lissie beds are dominantly gravel intermingled with sands and sandy clays. The formation is approximately 800–1,100 feet thick. These sands and gravel beds are water-bearing, and practically all of the water wells used for domestic purposes in the field are drilled into these beds for fresh-water production.

The first hard sands and calcareous nodular clays mark the top of the Citronelle formation, which is placed in the section as Upper Pliocene. This formation is characterized by reddish sands and sandy

clays with limestone nodules and ironstone conglomerates. A few calcareous, indurated, mud concretions are found associated with the clays. Siliceous gravel and boulders are found near the base of the formation 100–200 feet before penetrating the Fleming formation of Pliocene age. The thickness of the Citronelle formation ranges from 1,000 to 1,250 feet.

The Upper Fleming formation is characterized at the Jennings field by hard, calcareous, sandy shales, sands, and calcareous shales. This formation is generally referred to as the Lagarto, and in the lower part the shales are sandier and at the base the sands predominate. The Lagarto is 2,600–3,000 feet thick. The entire Pliocene is considered to be 3,600–4,000 feet thick.

The Lower Fleming, of Miocene age, is generally considered by others to be the Lower Lagarto and the Oakville formations. The formation as a whole is composed of sands with sandy shales, shales, and limestones. The sands are consolidated and well packed. *Rotalia beccarii* in this formation is large with prominent sutures. Reworked Cretaceous fossils are found in the formations in both sands and shales. The thickness of the Miocene ranges from 2,000–2,500 feet.

Below the Miocene beds, marine Oligocene is present, containing the typical *Discorbis* zone fauna and characterized by *Discorbis* cf. *D. vilardeboana*. The zone is composed of gray, well cemented, calcareous, friable shales interbedded with sandy shales and indurated sandstone. A few small beds of loosely consolidated sands are found interbedded with the sandy shales. The *Discorbis* zone section is 225–284 feet thick.

The *Heterostegina* zone is prominently present as very calcareous, indurated sandstone grading downward into sandy, calcareous shales and sands and at the base into coarse-grained, loosely consolidated sandstone. Typical *Heterostegina* zone *Foraminifera*, for example, *Heterostegina* cf. *H. antillea*, occur in abundance throughout the zone. The zone ranges in thickness from 125 to 300 feet.

The *Marginulina* zone is also determined paleontologically by typical *Marginulina* zone *Foraminifera*. The break from the *Heterostegina* zone to the *Marginulina* zone is very prominently marked by dark green shale under the *Heterostegina* sandstone, in which *Marginulina Foraminifera*, for example, *Marginulina* cf. *M. phillipensis*, are very plentiful. Under the shale is non-calcareous, compact, fairly coarse-grained sand, grading downward into greenish gray, calcareous, sandy shales and shales. The zone ranges in thickness from 400 to 475 feet.

No Frio formation has been encountered in any of the wells drilled on the southeast flank at Jennings.

The Vicksburg formation, Lower Oligocene in age, occurs below the *Marginulina* zone as carbonaceous shales grading downward to calcareous gray, dark gray, and blue shales interbedded with sandy shales and fine-to-medium-grained sands and sandstones. The formation is also characterized by typical Vicksburg *Foraminifera*. The formation has not yet been thoroughly penetrated, the deepest penetration being 646 feet.

A typical columnar section with paleontological guides of the southeast flank, as determined from wells, is shown in Table II.

TABLE II

TYPICAL WELL SECTION, SOUTHEAST FLANK, JENNINGS DOME

System	*Formation**	*Zone*	*Paleontological Guides*	*Thickness in Feet*
Pleistocene	Beaumont clay			25–100
	Lissie sands and gravels			800–1,100
Pliocene	Citronelle		*Rotalia beccarii*, small and worn. Some reworked Cretaceous	1,000–1,250
	Fleming (Upper Lagarto)		*Rotalia beccarii*, *Rangia johnsoni*, and reworked Cretaceous	2,600–2,750
Miocene	Fleming	Lower Lagarto	*Potamides matsoni*, found only as fragments in cuttings	2,000–2,500
		Oakville	*Rotalia beccarii*, large, prominent sutures	
Oligocene	Middle Oligocene	*Discorbis*	*Discorbis* cf. *D. vilarbeboana*	225–284
		Heterostegina	*Heterostegina* cf. *H. antillea*	125–300
		Marginulina	*Marginulina* cf. *M. phillipensis*	400–475
	Vicksburg		*Ammobaculites*, arenaceous *Foraminifera*, dark carbonaceous shales	646– Maximum penetration

* No Frio has been encountered on the southeast flank of the dome.

SUBSURFACE GEOLOGICAL AND GEOPHYSICAL STRUCTURE OF SOUTHEAST FLANK

The geological data obtained from the wells drilled on the southeast flank of the Jennings dome were combined with the geophysical data obtained as a result of a survey taken on that flank in 1932 by seismograph recordings. The geological conditions that were found to exist in wells drilled far from the flanks of the dome indicated that an overhang of the dome seemed highly probable, and the seismograph survey was conducted for the purpose of determining whether or not the dome is mushroomed below a depth of 5,000 feet, and, if so, of showing the extent of mushrooming by means of a profile calculated from the seismograph results.

The McCollum Exploration Company of Houston[8] conducted the actual survey of the flank. In this survey a modification of the standard refraction method was employed wherein a detector or recording device is lowered into a well near the flank of the dome to be tested. A detector was lowered into the Yount-Lee Oil Company's Houssiere-Latrielle well No. 10 near the southeast flank of the dome so as to occupy positions spaced at certain intervals from the top to the bottom of the hole, and a series of time values was thus obtained from shot points suitably located both on and off the dome. Tests were made at intervals of 250 feet from the surface down to 4,000 feet and at intervals of 100 feet from 4,000 to 5,000 feet near the knee of the dome; below 5,000 feet the intervals were 200 feet, with the last test at 7,600 feet. The total depth of the well is 8,762 feet, but it was not thought necessary to use the detector deeper than the 7,600-foot level.

At each position of the detector a series of shots was fired at points suitably located for determining both formation velocity in the vicinity of the dome and high velocity time values through the dome itself. These time values, when taken with their corresponding distances between shots and detector, give all the data necessary for calculating the point at which the seismic wave emerged from the dome in each instance. It is to be noted that the well in which the detector was spaced is located near the flank of the dome; this places the detector relatively close to the dome and eliminates the error involved in long distances traveled by the seismic wave through the different formations surrounding the dome. Unlike the standard profile procedure, in which both shot and detector are located on the surface, this method is not limited to points on the profile above the knee of the dome. In fact, the profile may be extended down to the deepest position occupied by the detector, irrespective of the shape of the dome flank.

The position of the shot points are shown in Figure 2. Shot *A* was established near well No. 85 for the purpose of obtaining the high velocity time values through the dome. Shots *B* and *C* were established at points 1,000 feet from the Houissiere-Latrielle well No. 10, one on the west toward the dome and the other on the east away from the dome. From these shots, shale velocities and their variation with depth were obtained; however, after the first few tests, shot *A* was abandoned because the high absorption encountered in this region

[8] Geophysical data compiled from a thesis entitled "Report on Seismograph Survey, East Flank of Evangeline Dome, for Yount-Lee Oil Company," by McCollum Exploration Company (July 25, 1932).

necessitated excessive charges of dynamite for satisfactory results. In the place of *A*, shot points *D* and *E* were established with much better results, although the absorption was still much higher than ordinarily encountered in salt-dome shooting. In replacing *A* by two "on dome" shot points, *D* and *E*, the thought was to use one for profile detail, reserving the other for check purposes only. Shot *D*, being the nearer of the two, gave better records with less dynamite and,

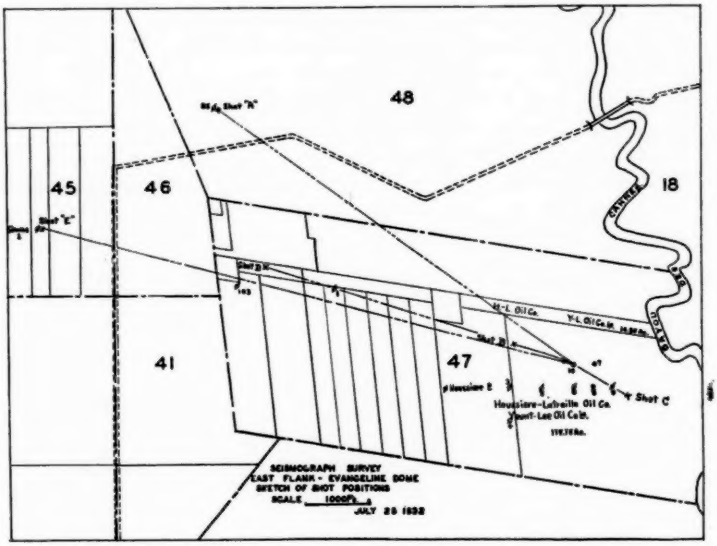


FIG. 2.—Sketch showing shot positions made for seismograph survey of southeast flank of Jennings dome.

consequently, was used for detail. At each depth setting of the detector a record was taken from *D*, and at intervals of 500–600 feet a record was taken from *E*.

The field work in connection with the foregoing program was started on July 6, 1932, and completed, July 18, 1932. During this time 119 shots were fired from the several shot points on 39 detector settings. A total of 3,445 pounds of dynamite was consumed, averaging 28.9 pounds per shot.

Figure 3 shows a cross section through the dome along a line connecting the Yount-Lee Oil Company's Houssiere-Latrielle well

No. 10 with shot points *D* and *E*. The direction of this line is approximately N. 75° W. The position of well No. 10 with respect to the flank of the dome is as shown. The deviation of the well from the vertical was determined from the Sperry-Sun test in a plane perpendicular to the flank of the dome. The maximum deviation of 116 feet occurs at the point of nearest approach of the well and the dome.

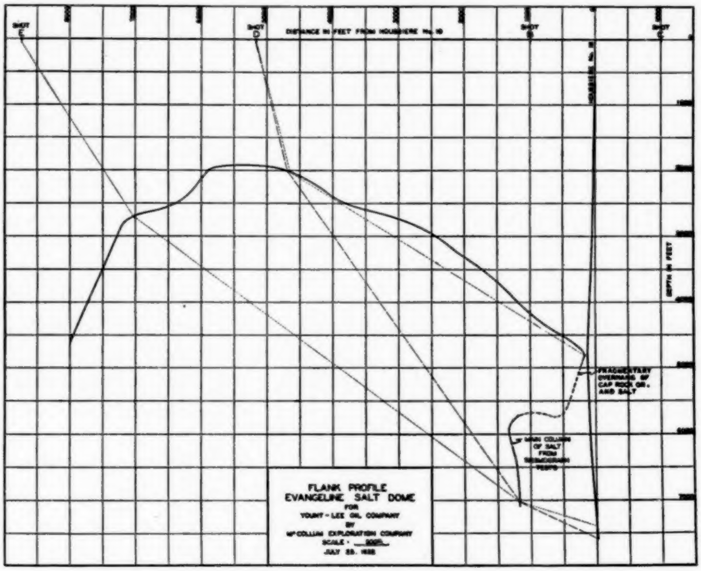


Fig. 3.—Flank profile showing position of shot well No. 10, shot points, and overhang of southeast flank, calculated from seismograph data.

The solid curve gives the dome profile for depths less than 4,600 feet, as obtained from well logs. This profile forms the basis for the flank profile calculations, giving as it does the entrance points for the seismic waves from the shot points.

On the east, below 4,600 feet, the profile was determined from the seismic time data, each dot representing a wave-emergence point from the dome mass. Considerable mushrooming is in evidence, with practically the full amount occurring between 4,750 and 5,950 feet. Below 5,950 feet and down to the final test point at 7,050 feet, the flank is approximately vertical, with only minor serrations in evidence. The lateral extent of the overhang is approximately 1,000 feet. As the tests show well No. 10 grazing the eastern extremity of the

dome, it may be concluded that the extreme flank of the salt proper lies 1,000 feet west of the well. Because of the character of the seismic waves obtained from the flank from 4,600 to 5,750 feet, it was impossible to differentiate the exact contact from cap rock and salt. It is of interest to note, however, that the record obtained for tests between 4,600 and 5,750 feet showed very poor transmission, indicating a broken condition or fingering of the cap rock overhanging the dome proper. In view of this, the dotted portion on the profile (Fig. 3) should be considered as showing only approximately the position of the fragmentary cap. Within this region masses of detached cap rock are encountered outside the dotted curve.

This accounts for the fragmentary and broken condition of the cap rock, as it has really been drilled in wells barely touching the edge of the cap rock. As shown in section *AA′* (Fig. 4), the Yount-Lee Oil Company's Houssiere-Latrielle No. 14 was drilled in and out of the cap rock in several places, as was the Yount-Lee Oil Company's Houssiere-Latrielle No. 11 shown in section *BB′* (Fig. 5), and the Yount-Lee Oil Company's Houssiere-Latrielle No. 13 shown in section *DD′* (Fig. 7). It is highly probable that the cap rock may not be wholly fingered as shown in the sections, as those ledges of cap rock encountered between 5,000 and 6,000 feet may be fragmentary ledges broken off the main body of cap rock during the upthrust of the dome, occurring as inclusions within the formations. The well data indicate small ledges and boulders of cap rock ranging from 2 to 50 feet in thickness, associated in broken and conglomerated strata. The poor seismic transmission observed in this region is thus checked by the well data. It is of interest to note that the exploration company conducting the survey was without the fragmentary cap-rock data as obtained from the well logs; this gives the seismograph report an unbiased and unprejudiced conclusion.

The tests made below 5,950 feet gave large and definite reflections like those from a solid salt mass. These define the extreme flank of the main column of salt. Because of the inconsistency of the records from 4,600 to 5,950 feet and the already existing impossibility of differentiating the cap-rock and salt reflections at that depth, it is highly probable, since the extension of the true salt mass occurs 1,000 feet from the shot well No. 10 and since the cap-rock overhang extends outward approximately 900 feet from the lower flank of the dome, that the salt body swings outward in relation to the cap rock and extends underneath the cap rock as part of the overhang. Thus, it is not probable that there is a cap-rock overhang of approximately 1,000 feet with no salt underneath.

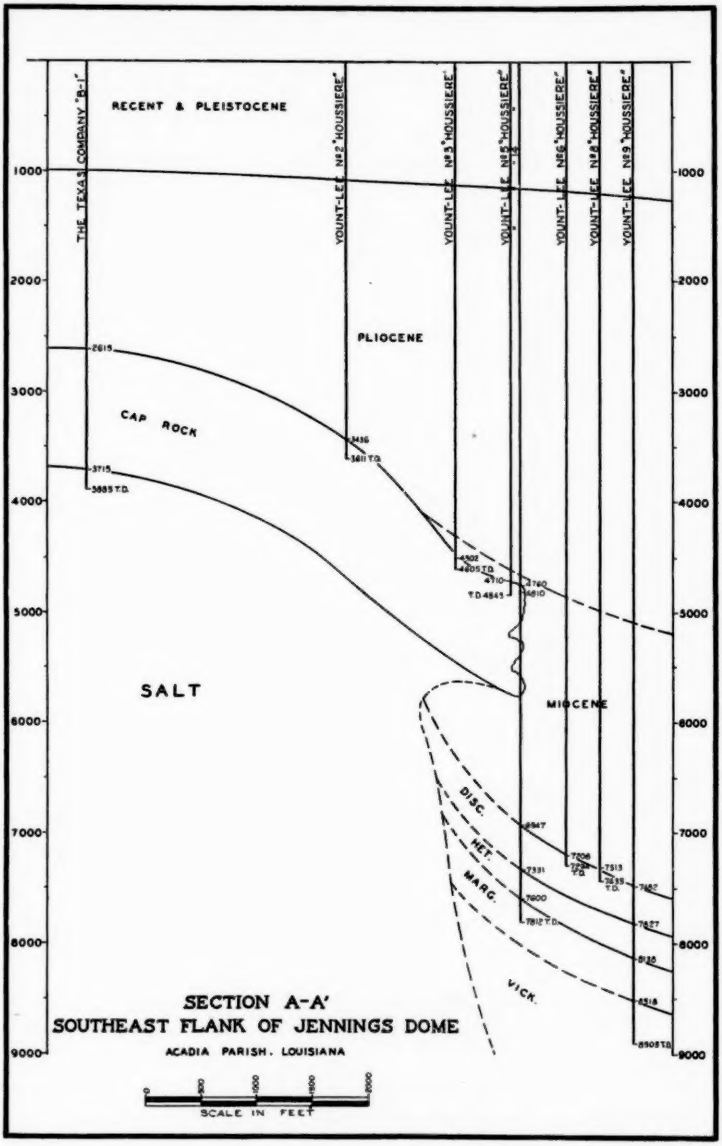


FIG. 4.—Section AA', southeast flank of Jennings dome. Location shown in Figure 9.

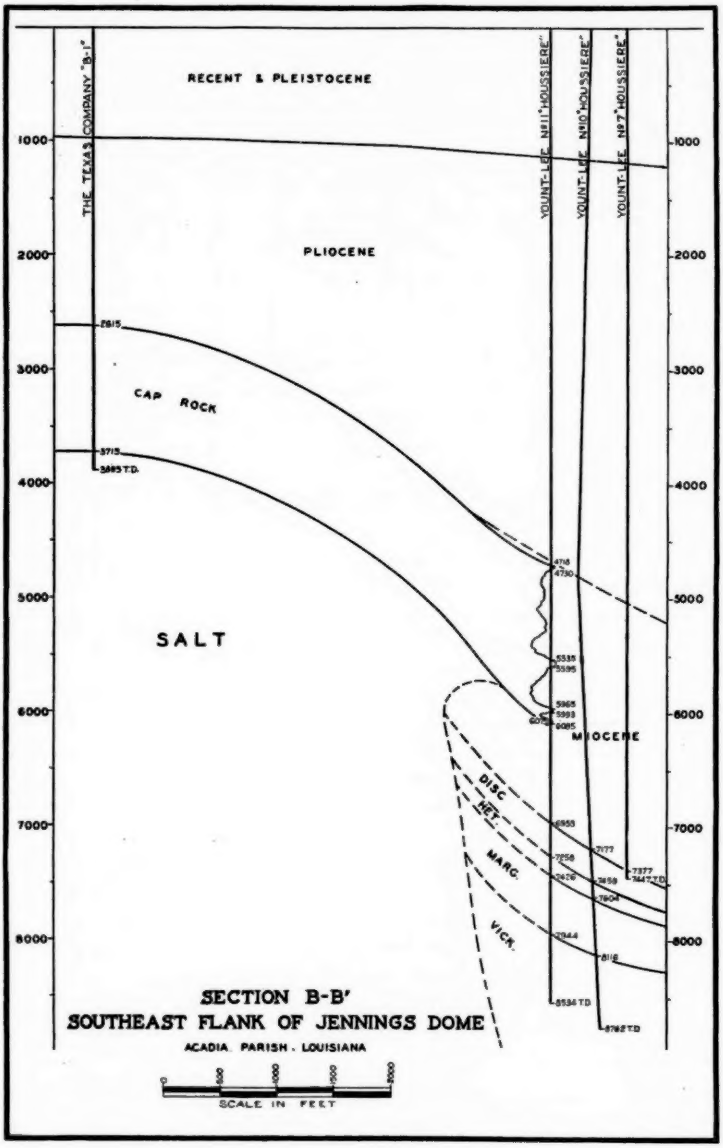
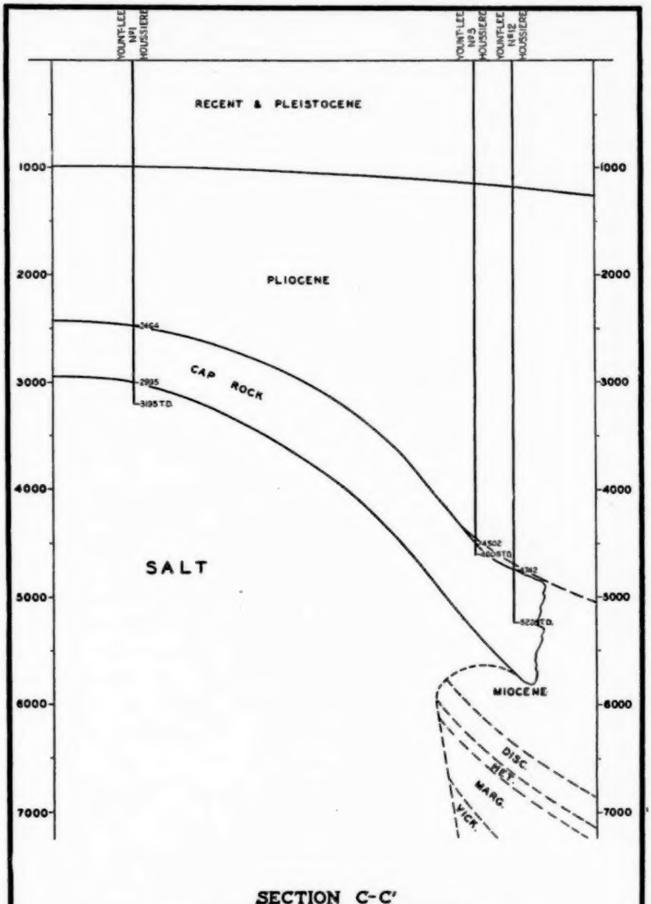


FIG. 5.—Section *BB'*, southeast flank of Jennings dome. Location shown in Figure 9.



SECTION C-C'
SOUTHEAST FLANK OF JENNINGS DOME
ACADIA PARISH, LOUISIANA

FIG. 6.—Section *CC'*, southeast flank of Jennings dome. Location shown in Figure 9.

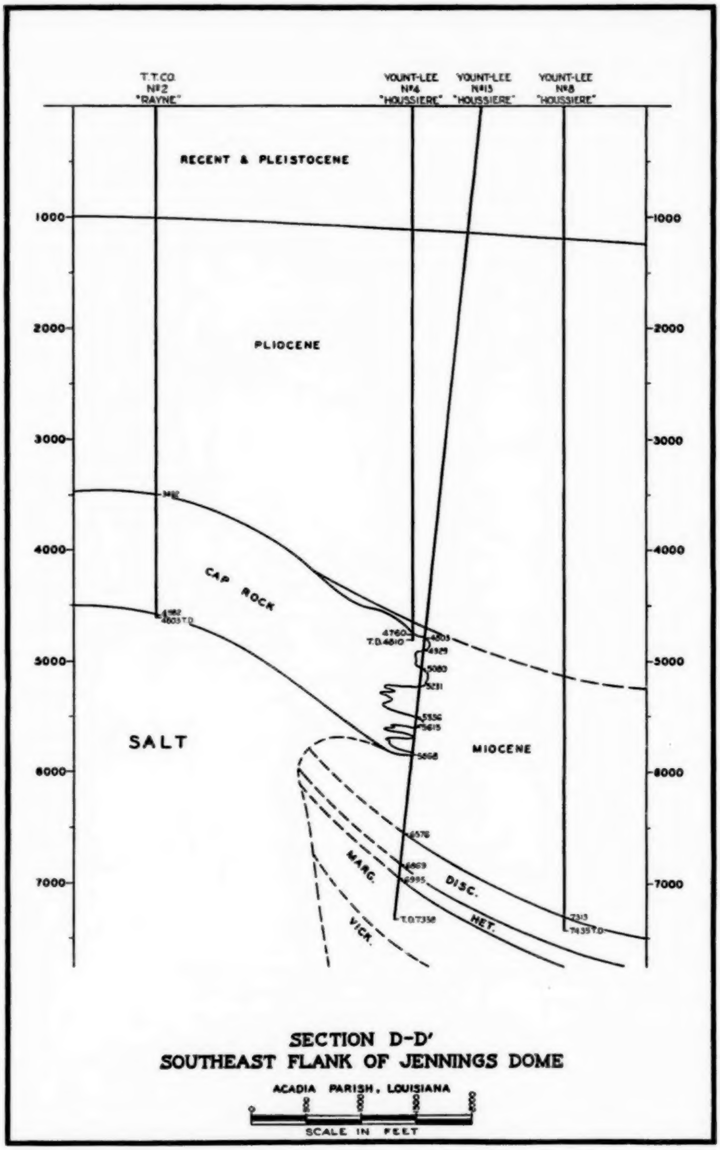


FIG. 7.—Section *DD'*, southeast flank of Jennings dome. Location shown in Figure 9.

It is probable that the relation between the salt overhang and the cap-rock overhang at Jennings is similar to the relation recorded on other domes, for example, Barbers Hill and High Island, Texas. Sections *AA'–DD'* (Figs. 4–7) show this relation. Cross section *EE'* (Fig. 8), as determined from geological and geophysical data, conforms with the data obtained from the geophysical profile (Fig. 3). In Figure 3 the overhang is recorded as fragmentary overhang of cap rock, or salt, or both. It is probable that the part above 5,750 feet is cap rock, and that the overhang proper below 5,750 feet and extending to the main salt flank is salt. The character of the results from which this profile was calculated would indicate a probable horizontal error of not more than 100± feet. Section *EE'* (Fig. 8), drawn through relatively the same line as Figure 3 and embodying well data and geological reasoning, shows the segregation of the cap rock and salt.

Both geological and geophysical data indicate a combined overhang of cap rock and salt of 1,000 feet extending domeward from the Yount-Lee Oil Company's Houssiere-Latrielle well No. 10. The character of the seismic results and well-log data indicates that part of this cap is probably broken off the main body of the cap rock, leaving the outside flank of the cap rock rugged and jagged.

Figure 9 shows the subsurface contour on top of the cap rock of the dome. According to this map, the contours on the southeast flank of the dome show a gradual and sloping structure, whereas on the other flanks the structure is more abrupt as the outward edge of the dome is approached. The locations of sections *AA'–EE'* (Figs. 4–8) are drawn on this map. All of these sections cross the southeast flank of the dome. The thickness of the cap rock was determined from controls taken from wells drilled on top of the dome and on its southeast flank. Section *EE'* (Fig. 8) shows the thickness of the cap rock across the dome. This section is more representative of the structure, as it is drawn through the center of the dome.

The marked deviation of the Yount-Lee Oil Company's Houssiere-Latrielle No. 13 as illustrated in section *DD'* (Fig. 7) is of interest. The determination was made from a Sperry-Sun test. The test was actually determined to a depth of 5,049 feet, the depth of the well at the time of the test, and the deviation from the vertical was 560 feet. The deviation began 200 feet below the surface. No attempt was made to straighten the hole after the test was made, and drilling was continued under the existing conditions. The deviation increased with depth, and it is estimated that the maximum deviation at the total depth of the hole, 7,358 feet, would be approximately 800 feet from

the vertical. Such a deviation places the well beneath the overhang and nearer the dome than the Yount-Lee Oil Company's Houssiere-Latrielle No. 4, though well No. 4 had been continued to a similar depth.

The Yount-Lee Oil Company's Houssiere-Latrielle No. 10 also had a maximum deviation of 116 feet from the vertical at 4,800 feet (sections *BB'* and *EE'*, Figs. 5 and 8), but the well was straightened to vertical before the total depth was attained at 8,762 feet.

PRODUCING HORIZONS

Oil in commercial quantity has been produced from the *Discorbis* zone, *Heterostegina* zone, and *Marginulina* zone, of Middle Oligocene age. The producing wells to date are the Yount-Lee Oil Company's Houssiere-Latrielle wells No. 6,[9] No. 8, No. 13, and No. 14. Wells No. 6 and No. 8 are producing from the Upper *Discorbis* zone and since their respective completions on June 2, 1929, and June 14, 1930, have produced together more than 1 million barrels of oil. Well No. 13 is producing from a body of sand 123 feet thick, from the *Marginulina* zone. This sand lies immediately under the dark green shale at the extreme top of the zone. Well No. 14, recently completed, is producing from both the *Heterostegina* and *Marginulina* zones. Productive sands in this well are present 50 feet below the top of the *Heterostegina* zone and with small breaks extend down into the *Marginulina* zone. The dark green shale at the top of the *Marginulina* zone is almost pinched out, with a thickness of only 8 feet. Fortunately, a core was taken through it, and its physical and lithologic characteristics, as well as the presence of *Marginulina* fauna marked by the abundance of *Marginulina* cf. *M. phillipensis*, clearly separate the two zones. The lithologic characteristics of the *Heterostegina* sands differ from those of the *Marginulina*. Sands encountered in this well are at the following depths in feet: 7,383–7,407; 7,539–7,557; 7,560–7,564; 7,580–7,588; 7,608–7,618; 7,624–7,662; and 7,683–7,804. Screen was set in all of the sands.[10] Shale was present between the

[9] The zonal and formational contacts in the Yount-Lee Oil Company's Houssiere-Latrielle wells No. 6, No. 7, No. 8, and No. 9 were estimated by correlation from dips and paleontological data obtained from wells No. 10, No. 11, No. 12, No. 13, and No. 14. As wells No. 6, No. 7, No. 8, and No. 9 were drilled before the existence of the present Yount-Lee Oil Company's geological and paleontological department, and as no cores were saved, the company, unfortunately, was without correct paleontological data.

[10] Since the completion of this paper, the Young-Lee Oil Company's Houssiere-Latrielle No. 14 made more than 75 per cent salt water in its daily production, and it was necessary to pack off the first four sands (from 7,383 to 7,588 feet) finally to bring the well in as a pipe-line oil producer with an initial flow of 840 barrels on choke. Therefore, the well at present is producing clean oil strictly from the *Marginulina*

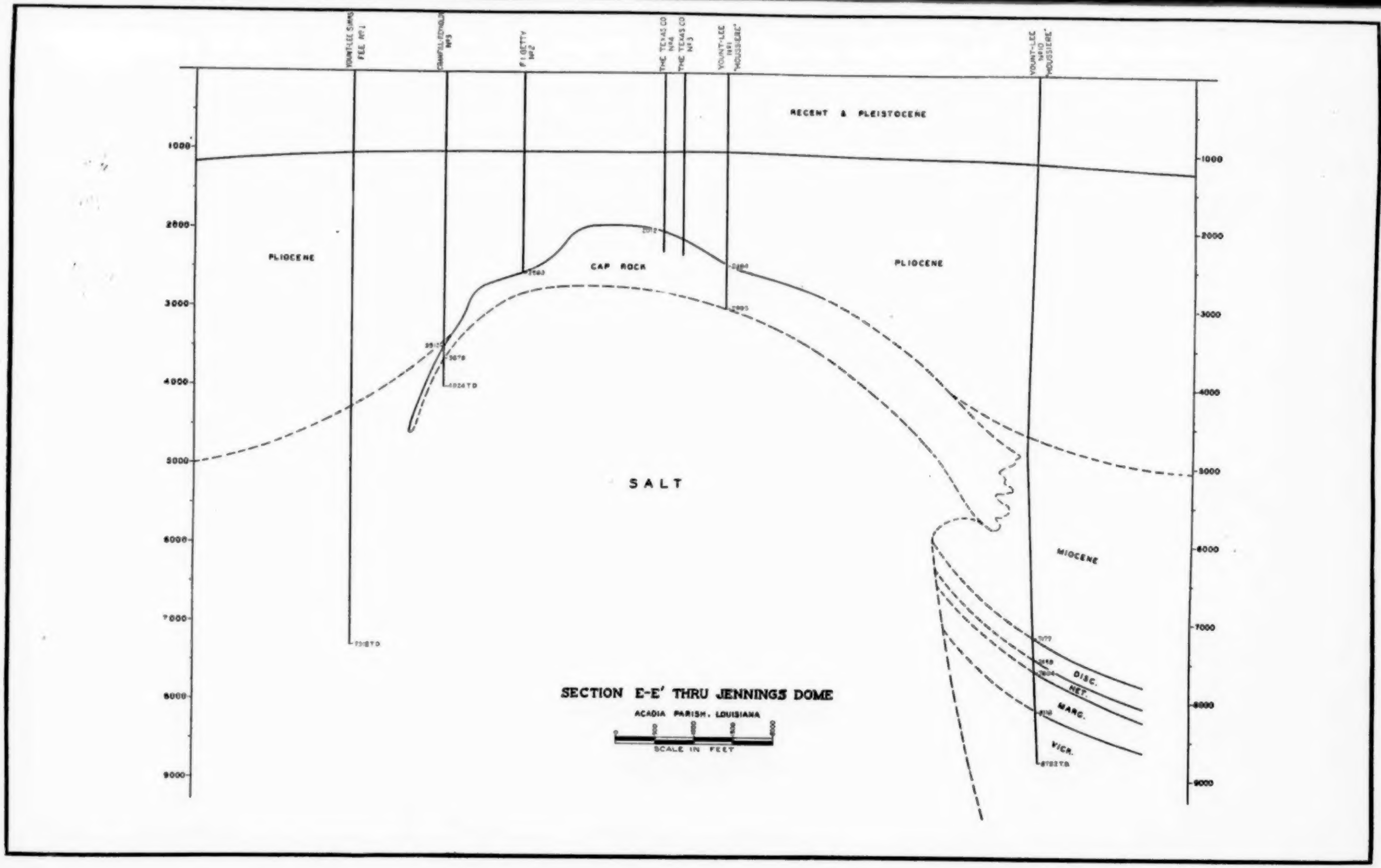


FIG. 8.—Section *EE'*, southeast flank of Jennings dome. Location shown in Figure 9.

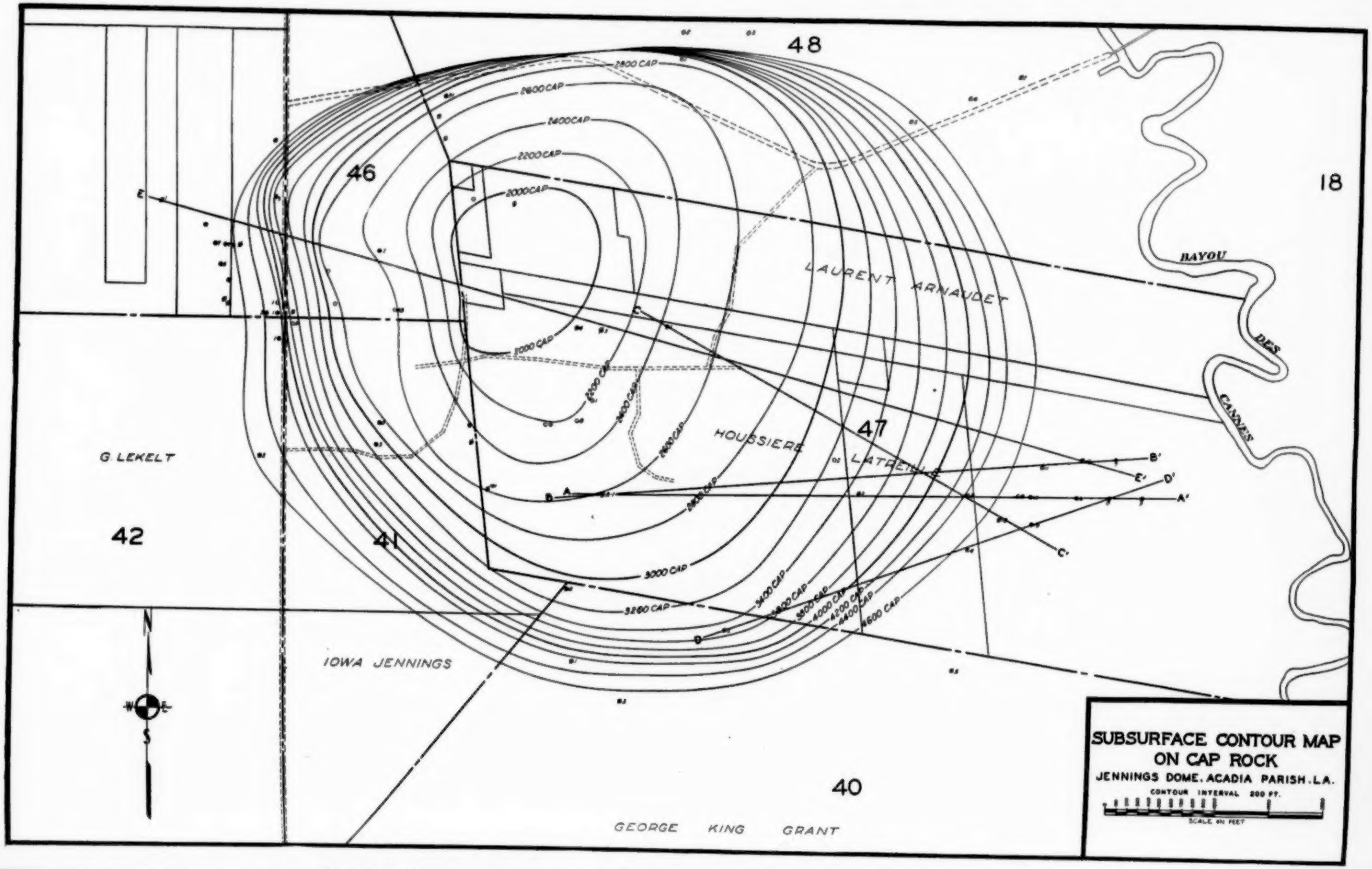


FIG. 8.—Subsurface structure map of Jennings dome, contoured on cap rock below sea-level.

sands. From 7,588 to 7,600 feet, gray shale and hard sandy limestone of *Heterostegina* age were cored and, from 7,600 to 7,608 feet, the dark green *Marginulina* shale was encountered. This contact is one of the most clearly defined in the entire well.

The Yount-Lee Oil Company's Houssiere-Latrielle No. 7, although not producing at present, also produced from the *Discorbis* zone.

The Yount-Lee Oil Company's Houssiere-Latrielle wells No. 9, No. 10,[11] and No. 11 did not encounter any oil or gas showings in the Middle Oligocene zone, although each well was drilled into the Vicksburg formation of Lower Oligocene age. Oil and gas showings, however, were encountered in the Vicksburg formation in fine-grained and well packed sand. The sand in well No. 10 was tested for production, but produced only a little gas, with no oil, and was finally abandoned.

As the Yount-Lee Oil Company's Houssiere-Latrielle wells No. 9, No. 10, and No. 11 did not encounter the Middle Oligocene oil sands, it is highly probable that the producing sands are irregular and pinched out with lensing. No indications of faulting in the formations have been noticed, as the formations seem to be regular with the respective positions of the wells and the formational and zonal contacts in each. The *Marginulina* sand is a new horizon for production on this flank, and both of the wells producing from this zone are under the overhang. Such a large body of sand may be regular and may

ANALYSES OF OIL FROM *DISCORBIS* ZONE

(Houssiere-Latrielle wells No. 6 and No. 8)

Gravity	28.3° A.P.I.
Flash (open-cup)	140° F.
Fire	175° F.
Saybolt viscosity	63 at 100° F. 48 at 130° F.
Paraffine	0.90 per cent
Sulphur	0.17 per cent
Color	Light green
Pour	−0° F.
Basic sediment and water	None
Initial boiling point	82° F. (vapor)
Untreated gasoline	14.75 per cent crude
Untreated light gas-oil	27.15 per cent crude
Heavy gas-oil	18.10 per cent crude
Lubricating stock	39.70 per cent crude
Final vapor temperature	543° F.
Final liquid temperature	759° F.

sands, from 7,608 to 7,804 feet. The *Heterostegina* sands were doubtful in the primary setting, and, when salt water in large quantities was associated with the oil, the sands in this zone were immediately packed off, preventing further production from this zone.

[11] M. T. Halbouty, "Vicksburg Formation in Deep Test, Acadia Parish, Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 6 (June, 1932), pp. 609–10.

ANALYSES OF OIL FROM *MARGINULINA* ZONE

(Houssiere-Latrielle No. 13)

Gravity	34.0° A.P.I.
Flash (open-cup)	Too light
Fire	Too light
Saybolt viscosity	47 at 100° F. 38 at 130° F.
Paraffine	1.14 per cent
Sulphur	0.10 per cent
Color	Dark green
Pour	−0° F.
Basic sediment and water	None
Initial boiling point	114° F. (vapor)
Untreated gasoline	29.50 per cent crude
Untreated light gas-oil	20.50 per cent crude
Heavy gas-oil	10.25 per cent crude
Lubricating stock	39.50 per cent crude
Final vapor temperature	580° F.
Final liquid temperature	746° F.

extend farther domeward underneath the overhang, and future locations may be governed with this factor in mind.

All of the producing sands in the Middle Oligocene zones are firmly packed and well consolidated and can be classified as high-pressure sands. Drilling muds must be kept at a relatively great weight to prevent blow-outs. The *Discorbis* sands are fine- to medium-grained, the *Heterostegina* sands are medium- to coarse-grained, and the *Marginulina* sands are equally medium- to coarse-grained. The lithologic characteristics of the sands in each zone are distinctly different.

SUMMARY OF CONCLUSIONS

The Jennings salt dome has been proved only since 1929 to be productive on the southeast flank. Previously, production had been limited entirely to the super-dome sands and cap. Although drilling exploration has been conducted on the south, north, and west flanks with no success of commercial production, the possibilities of production from these flanks may eventually be shown by detailed drilling through a possible overhang. It is conclusive from compiled geological and geophysical data that an overhang of both cap rock and salt of approximately 900 feet exists on the southeast flank.

Oil has been produced from the Middle Oligocene formation. The *Discorbis* zone and *Marginulina* zone have been the most prolific. The *Heterostegina* zone sands are fairly saturated with oil; however, no separate setting in this zone has been made. The *Marginulina* sands have only recently been proved to be productive with the completion of the Yount-Lee Oil Company's Houssiere-Latrielle wells No. 13 and

No. 14. The sands in the Middle Oligocene zones are not regular, and probable pinching-out or lensing is indicated from the fact that other wells drilled through these zones did not encounter oil showings. No indications of faulting have been detected. It is probable that in the future oil in large quantities may be produced from sands underneath the overhang proper, as wells No. 13 and No. 14 are producing from the *Marginulina* sand found beneath this overhang.

No Frio formation of Lower Oligocene age has been encountered in wells drilled on the southeast flank.

The Vicksburg formation, of Lower Oligocene age, has been penetrated to a maximum thickness of 646 feet. A few scattered thin oil showings were reported in this formation, but none has been proved productive to date. It is probable that the Vicksburg sands would produce commercially if sufficient thicknesses of oil sands were found, since the small thicknesses already encountered contained exceedingly high gas pressures, but a very small percentage of oil saturation.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), PP. 1330-1338, 2 FIGS.

STRUCTURAL FEATURES OF BRENHAM SALT DOME WASHINGTON AND AUSTIN COUNTIES, TEXAS[1]

SELWYN O. BURFORD[2]
Lake Charles, Louisiana

ABSTRACT

The Brenham salt dome, located in the center of the Texas Gulf Coastal Plain, and discovered prior to 1915 by the drilling of a shallow water well, is a typical piercement dome, shown by the 2,950-foot uplift of the Crockett formation. The maximum thickness of cap rock is 722 feet. The thinnest section encountered is on the east side of the dome, where an 89-foot section of cap rock was drilled before the salt was encountered. The greatest amount of uplift occurs at this point and the thin cap suggests that a section of several hundred feet was eroded before deposition of the Crockett. Wells drilled on and around this structure have been discouraging as to possible super-cap, cap-rock, and flank production.

INTRODUCTION

No information has been published concerning the Brenham salt dome except by O. B. Hopkins in 1917.[3] Since then several deep wells have been drilled on and around this structure. Unfortunately the data from some of these wells are not available because no records were kept. This paper summarizes all data now available, the salient features of which are presented by a partial contour map of the cap rock, as well as a more or less idealized northwest-southeast profile section through the dome.

PHYSIOGRAPHY

The Brenham salt dome is about 75 miles northwest of Houston, near the center of the Texas Gulf Coastal Plain, in the S. M. Williams and John Hodge surveys, on the Washington-Austin County line, 9 miles southwest of the town of Brenham, from which it takes its name.

The topography of this area is of the smoothly rounded, rather steeply rolling prairie character so typical of the bentonitic and sandy

[1] Manuscript received, June 20, 1935.

[2] Geologist, Humble Oil and Refining Company. For permission to publish this information, the writer is indebted to the Humble Oil and Refining Company. He is also indebted to L. P. Teas of the Humble Oil and Refining Company, for encouragement and helpful criticism in the compilation and accomplishment of the paper. Thanks are also extended to Donald C. Barton and W. B. McCarter of the same company, for the examination and criticism of the paper, and to F. W. Rolshausen of the company's subsurface laboratory, and his corps of workers, for information concerning the geologic section encountered in the various wells examined in this discussion.

[3] O. B. Hopkins, "The Brenham Salt Dome, Washington and Austin Counties, Texas," *U. S. Geol. Survey Bull. 661* (1917).

clays of the Miocene formation of the Texas Coastal Plain. The maximum relief in this area is 60 feet, and the average elevation is 275 feet above sea-level. Neither the topography nor the drainage pattern is suggestive of structural abnormality in the surface strata.

HISTORY OF DEVELOPMENT

Prior to 1915 a shallow water well was drilled near the south corner of the F. W. Shuerenberg 196-acre farm, in which heavy black oil was discovered at 104 feet. This well was drilled to a depth of approximately 500 feet; but no further showings were recorded. This discovery led to the immediate drilling of several wells in this vicinity, in a few of which anhydrite and salt were encountered.

In 1917, O. B. Hopkins[4] compiled the data on this structure which proved the existence of a salt dome.

Additional data on the position of the cap rock were revealed later by several deep and shallow tests. The most important of these wells are the Pen-Tex Kamas Nos. 1 and 2; the Texas Company's F. Pomical No. 1 and Theilman No. 1; and Fitzsimmons (Horns Petroleum Company) F. W. Shuerenberg No. 1. The cap rock was encountered in all of these wells and in two of them rock salt was also found beneath the cap.

Three important tests were drilled more recently and far enough away from the salt dome to miss the cap rock. They are The Texas Company's Theilman No. 2, the Deep Test Company's (Baker *et al.*) Kramer No. 1; and Pratt *et al.* Konieczny No. 2. The first two are important in that good records of the formations were kept. On the last, only the driller's log is available, but the well is important because it was drilled to a depth of 3,152 feet without encountering the cap rock, and is located within a few hundred feet of the Pratt *et al.* Konieczny No. 3, in which cap-rock material was encountered at 1,321 feet below sea-level. In the Pratt Company's Konieczny No. 1, an oil sand was discovered just above the cap rock and the well was reported to have flowed 35 barrels of oil per day for 2 or 3 days. Later this well ceased to flow and was subsequently abandoned.

The only producing well which has been completed below the 100–200-foot shallow sands is the Brenham Oil Company's Shuerenberg No. 2, in which an oil sand was encountered at approximately 1,046 feet below sea-level or just above the cap rock. This well produced 2–5 barrels of oil per day for a period of about 2 years. The other relatively deep wells have had no important showings.

Shallow production on this dome was developed soon after the

[4] *Op. cit.*, pp. 271–80.

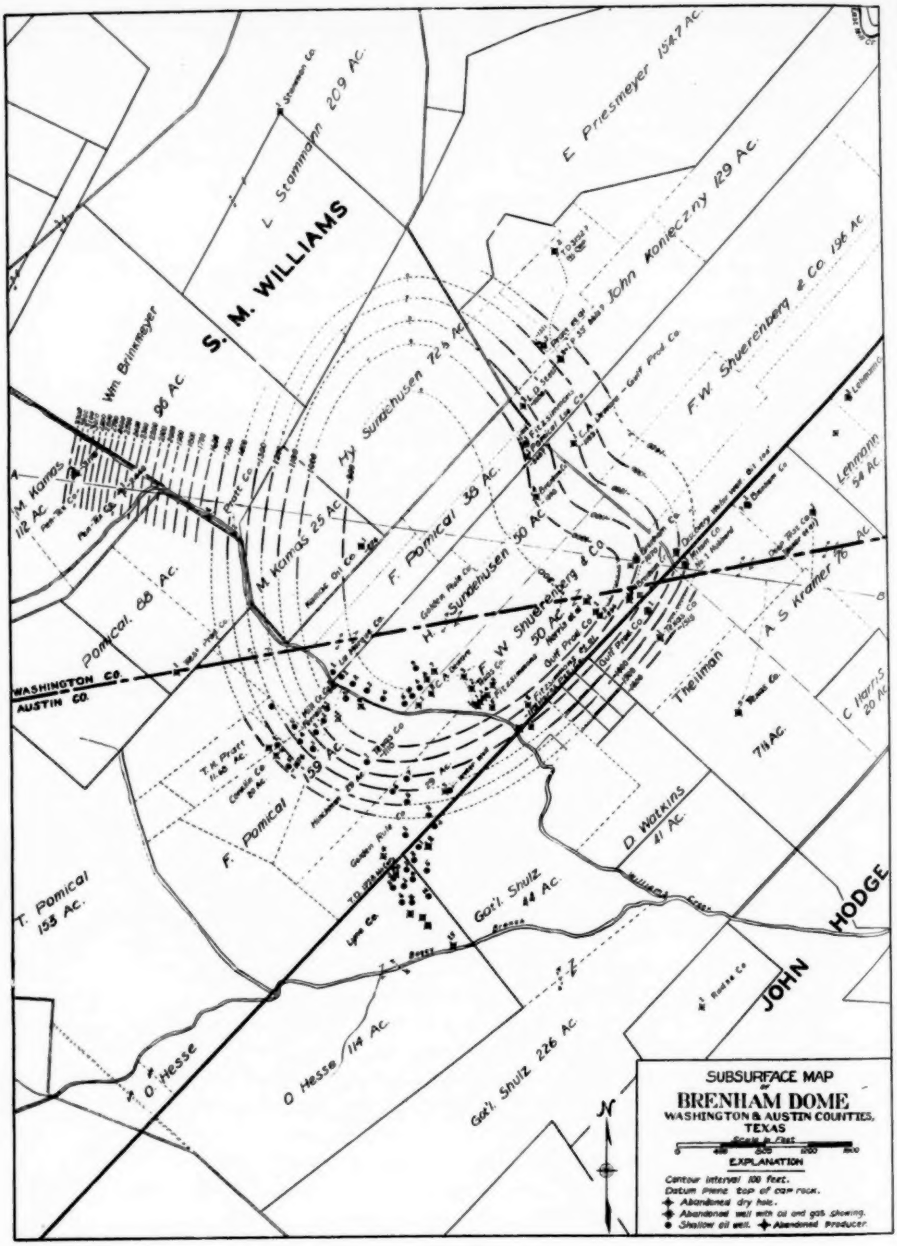

SUBSURFACE MAP
of
BRENHAM DOME
WASHINGTON & AUSTIN COUNTIES, TEXAS
Scale in Feet
EXPLANATION
Contour interval 100 feet.
Datum Plane top of cap rock.
Abandoned dry hole.
Abandoned well with oil and gas showing.
Shallow oil well.
Abandoned Producer.
S. M. WILLIAMS
JOHN HODGE
WASHINGTON CO.
AUSTIN CO.
E. Priesmeyer 154.7 Ac.
L. Stammann 209 Ac.
John Konieczny 129 Ac.
F.W. Shuerenberg & Co. 196 Ac.
Wm. Brinkmeyer 96 Ac.
Hy. Sundehusen 72.5 Ac.
M. Kamas 112 Ac.
M. Kamas 25 Ac.
F. Pomical 38 Ac.
H. Sundehusen 50 Ac.
Pomical 88 Ac.
F. W. Shuerenberg & Co. 50 Ac.
F. Pomical 159 Ac.
T. Pomical 153 Ac.
Lehmann 54 Ac.
A. S. Kramer 76 Ac.
Thellman 71 Ac.
C. Harris 20 Ac.
D. Watkins 41 Ac.
Gott'l. Shulz 44 Ac.
Gott'l. Shulz 226 Ac.
O. Hesse 114 Ac.
O. Hesse
Williams Creek
N

FIG. 1

discovery of the 104-foot horizon in the F. W. Shuerenberg water well. This heavy black oil was sold locally for fuel, and is still being produced for that purpose. Between 25 and 45 of these shallow wells were completed on the south side of the structure; they usually pump 1–5 barrels per day per well. During October, 1934, according to the latest data available, 29 shallow wells were being pumped, which produced a total of 854 barrels during that 30-day period.

REGIONAL GEOLOGY

Surface features.—The Brenham dome lies beneath the outcrop of the uppermost Oakville beds, which are composed principally of gray and yellow bentonitic clays with several brown cross-bedded and lenticular sand and sandstone members. Many of these sandstone beds contain worn or reworked Cretaceous and other fossil shells and bone fragments. The bone fragments and skeletal remains, however, are indigenous.

The contact of the Oakville and Lagarto formations lies near the southeast edge of the Brenham salt dome. This contact is rather difficult of delineation, as the sands and clays of each formation are similar. The main characteristic of the Lagarto is its greater percentage of argillaceous material, whereas the Oakville contains a higher percentage of sand. This contact is marked by a change from the grayish brown sandy clay soils of the upper sand member of the Oakville to the black waxy clay soils of the basal clay section of the Lagarto.

Subsurface features.—In Washington and Austin counties, the subsurface formations from the Catahoula downward through the Jackson, and perhaps the upper part of the Claiborne, have a regional strike paralleling that of the surface beds. There are not enough subsurface data below the base of the Jackson to determine accurately the regional strike of the Claiborne and deeper formations. It is probable that they have the same strike as that of the formations higher in the section.

The base of the Jackson in this region normally lies at a depth of approximately 3,100 feet below sea-level on the line of strike through the Brenham dome. The normal thickness and sub-sea position of the various formations from the surface down as deep as data are available, are shown by the well section of the Tom Owens (Inland) Oil Company's Weiss No. 1, located approximately 4.5 miles northeast of the Brenham dome. This well section is shown in the profile section (Fig. 2).

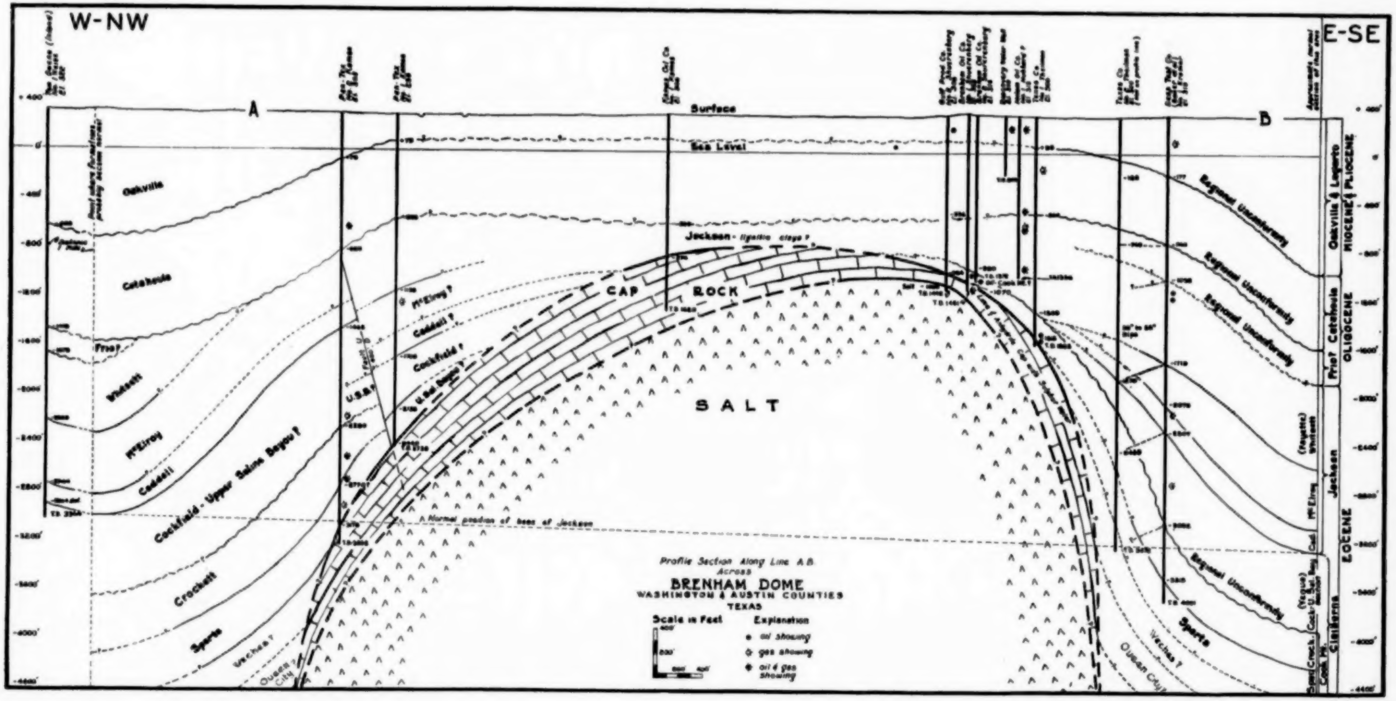

W-NW
E-SE
A
B
Surface
Sea Level
Oakville
Catahoula
Frio?
Whitsett
McElroy
Caddell
Cockfield - Upper Saline Bayou?
Crockett
Sparta
Weches?
Queen City
Jackson - lignitic clays?
CAP
ROCK
SALT
McElroy?
Caddell?
Cockfield?
U.S.B.
Normal position of base of Jackson
Regional Unconformity
Regional Unconformity
Regional Unconformity
Regional Unconformity
Weches?
Queen City
Oakville & Lagarto
MIOCENE & PLIOCENE
Frio? Catahoula
OLIGOCENE
Jackson
EOCENE
Claiborne
Profile Section Along Line A-B
Across
BRENHAM DOME
WASHINGTON & AUSTIN COUNTIES
TEXAS
Scale in Feet
Explanation
oil showing
gas showing
oil & gas showing

FIG. 2

LOCAL STRUCTURE

Surface indications.—The Oakville-Lagarto contact crosses Washington and Austin counties, approximately from northeast to southwest, near the southeast edge of the Brenham dome. The salt movement probably ceased before the close of Oakville time, as there is no noticeable abnormality in the dip or strike of these beds in the immediate vicinity.

The salt dome lies between East Mill Creek and Williams' Creek, and the latter, which is the smaller, flows over the south part of the salt dome. This drainage pattern causes the north end of the dome to be covered by a normal east-west topographic ridge lying between the two creeks, which ranges from an elevation of 300 feet near the junction of East Mill and Williams' creeks to an elevation of 375 feet on the northwest, in the vicinity of the Stamman Oil Company's well north of the dome. Farther west, 1–1.5 miles, this ridge rises to an elevation of 385 feet. These elevations are normal, as compared with the average topography of the Oakville and Lagarto formations in adjacent territory.

Subsurface structure.—The well data available for the subsurface study of this structure are anything but satisfactory. This is particularly true of those wells drilled during the earlier development of the field. Some of those wells, for which there are scant data, have been omitted from the map. On the map will be found an incomplete contour picture of the cap rock, which reflects a slightly ovate elliptical body, the major axis of which bears N. 5° E.

The impression that the dome leans slightly eastward from a vertical position is given by the data of Figure 2. It must be remembered, however, that the control points of this profile section are widely separated, and that the top of the cap rock in some of the wells was taken from drillers' logs of old wells completed many years ago. Therefore, the authenticity of this picture is not guaranteed.

An abundance of wells on the south and east sides of the dome give a more detailed picture of that part of the cap, and a fair idea of the position of the cap on the southwest side is given by two wells. Three wells on the west side of the dome show the dip of the cap rock there. The dip of the cap from the Kamas Oil Company's Kamas No. 1, northwestward to the Pen-Tex Company's Kamas No. 1, across the edge of the dome, is 2,305 feet in 2,650 feet, or 4,592 feet per mile. The flattening shown on top of the dome in the vicinity of the Kamas Oil Company's Kamas No. 1, and the sharp dip between this well and the Pen-Tex Company's Kamas No. 1, is assumed so that the contours here reflect the shape of the cap shown by the contours between

wells which afford better control on the opposite side of the dome. The dip shown by the contours on the accompanying map (Fig. 1), therefore, does not conform to the average dip figured above. The dip of the cap from the Pen-Tex Company's Kamas No. 1, northwestward to the Pen-Tex Company's Kamas No. 2, steepens to 9,240 feet per mile. The cap-rock formation should show a fault between these two wells, as shown in the formations above the cap, but without additional holes in this vicinity, it can not be determined whether the cap is faulted. So far as is known, this fault is not present in the surface formations.

The average dip of the cap from the Kamas Oil Company's Kamas No. 1, southwestward to the Conklin Oil Company's F. Pomical No. 5, is 600 feet in 1,300 feet, or approximately 2,436 feet per mile. On the southeast side of the dome, between the Gulf Company's F. W. Shuerenberg No. 2 and The Texas Company's Theilman No. 1, the average dip is 521 feet in 600 feet, or 4,584 feet per mile.

The flank of the cap rock between The Texas Company's Theilman No. 1, and The Texas Company's Theilman No. 2, in the east quadrant, very probably is vertical, as shown on the cross section. The former well went into the cap at 1,515 feet below sea-level. The latter well and the Deep Test Company's Kramer No. 1, both farther away from the dome, did not encounter the cap rock to total depths of 3,572 and 4,001 feet, respectively, but both wells revealed dips of 35°–55° in the deeper beds.

A pronounced nose extending eastward on the edge of the dome, in the vicinity of the discovery water well, just north of the county line in Washington County, is shown by the contours on top of the cap. This nose is also reflected in the formation tops in the area between the Deep Test Company's Kramer No. 1 and The Texas Company's Theilman No. 1.

GEOLOGIC HISTORY

No definite surface evidence to indicate a structure in this area seems to be present, for reasons previously discussed. The subsurface data, however, reveal a pre-Miocene piercement salt dome (Fig. 2).

The Crockett formation lies directly on the cap rock except on the west side of the dome. According to the literature[5] on this structure, Crockett fossils were identified from the Gulf Company's Theilman No. 1, and the Brenham Oil Company's Shuerenberg No. 1 at positions directly above the cap rock. The Harris Company's Shuerenberg No. 1, 400 feet west of the Brenham Company's Shuerenberg

[5] O. B. Hopkins, *op. cit.*, p. 274.

No. 1, obtained definite Crockett fossils, *Eponides guaybelensis, Ceratobulimina eximia*, and *Asterigerina texana*, from a core at 1,180 feet, approximately 80 feet above the cap rock. The information from the wells on this edge of the dome is, therefore, consistent in showing at least remnants of the Crockett formation immediately above the cap rock. On the west side of the dome, this condition does not exist, as Cockfield and younger formations are shown to lie just above the cap rock in the Pen-Tex Company's Kamas No. 1 at this point.

The major part of the salt movement took place subsequent to Crockett time and ended prior to the end of Jackson time. The greatest amount of uplift occurred on the east or southeast side of the dome. By estimating the normal subsurface position of the Crockett in this area, it may be seen that the salt dome mass moved upward through the formations a distance of 2,950 feet since the close of Crockett time. This conclusion is based on data from the Tom Owens (Inland) Oil Company's Weiss No. 1, located 4.5 miles northeast of the Brenham dome, and approximately 1.5 miles northwest of the normal line of strike through the northwest edge of the structure. By using the thickness of the Cockfield encountered in near-by wells to estimate the depth of the top of the Crockett at the position of the Tom Owens well, this formation should normally lie at 3,900 feet below sea-level on the southeast side of the dome, whereas the Gulf Company's Shuerenberg No. 1 encountered the Crockett at 950 feet below sea-level.

The greater part of the uplift of the salt core seems to have ended before the latter part of the Jackson period, for there is a section of 400–600 feet of lignitic and chocolate shales lying on the cap rock which may be assigned to the Jackson formations. The faulting on the north edge of the dome, between the Pen-Tex Company's Kamas Nos. 1 and 2, probably occurred during this period of uplift and before Catahoula time. The geologic section, from the base of the Catahoula down, in the Kamas No. 1, appears to have dropped approximately 400 feet, as compared with the section in the Kamas No. 2. As far as is known, this displacement does not exist in the Catahoula. It is assumed, therefore, that the faulting occurred after the Jackson or between that and the Catahoula, when the Jackson sediments were exposed, eroded, submerged, and overlapped by the Catahoula.

It is interesting to notice that the Catahoula, like the Crockett, shows the greatest amount of movement on the east side of the dome. The base, as well as the top of the Catahoula, shows about 800 feet of uplift on the west side of the dome, and approximately 1,000 feet of uplift on the east side. The thickness of this formation is fairly

consistent except on the north side of the dome, where there is an increase in thickness of about 200 feet.

Slight erosion of the Catahoula seems to have taken place before the beginning of Miocene time, after which the small island or shallow shoal of Catahoula was "swallowed up" by the thickening of the Oakville deposits, with the gradual subsidence of the Miocene sea bottom. Since the deposit of the Oakville, there has been little, if any, local uplift in this area.

Truncation of the cap rock is a feature of the pre-Crockett history of the dome. In the Gulf Production Company's Shuerenberg No. 2, on the east edge of the dome, salt was encountered at 1,083 feet below sea-level after drilling 89 feet of cap-rock formation. Drilling continued in the salt for 50 feet. In the Kamas Oil Company's Kamas No. 1, near the west center of the dome, a 440-foot section of cap-rock formation was drilled and the well was abandoned in the cap rock. In The Texas Company's F. Pomical No. 1, on the south edge of the dome, a 700-foot section of cap-rock formation was drilled before the salt core was encountered. The thin section of cap encountered in the Gulf well suggests truncation of the cap, over which the Crockett formation was later deposited. This seems plausible, since the greatest amount of uplift is in this immediate vicinity.

GENERAL OBSERVATIONS CONCERNING CAP-ROCK DATA

The following section through the cap rock is found in many of the wells on the dome: crystallize limestone in small quantities, gypsum in very small quantities, and 400–700 feet of anhydrite above the rock-salt core. The greatest penetration of rock salt is shown by the log of The Texas Company's F. Pomical No. 1, located near the south end of the dome. It is interesting to relate that in this well there was between 60 and 70 feet of limestone cap, apparently no gypsum, and approximately 730 feet of anhydrite before the salt was reached. The 60–70-foot section of lime cap is apparently the maximum for this salt dome, as other wells had either no calcite or only small quantities. In the three Texas Company wells, salt and sulphur water occurred in the top of the cap rock. This is also true of many of the other wells on the south and east sides of the dome.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), PP. 1339-1356, 1 FIG.

STRATIGRAPHY OF NORTHEASTERN AND EAST-CENTRAL PARTS OF SOUTH PARK, COLORADO[1]

J. HARLAN JOHNSON[2]
Golden, Colorado

ABSTRACT

South Park is a depressed park-like area surrounded by mountains in central Colorado. The stratigraphy of the northeastern and east-central parts of the park are described. The beds range in age from Permian to Pleistocene. The formations described are the Maroon (Pennsylvanian and Permian); Morrison (Jurassic); the Dakota sandstone, Benton shale, Niobrara limestone and shale, Pierre shale, Fox Hills sandstone, and Laramie formation, all of Cretaceous age; and the Denver formation and Lake Beds of Tertiary age. The distribution, lithologic character, age, and relations of each are described, and the beds are compared with the corresponding deposits east of the Front Range.

INTRODUCTION

South Park is a relatively depressed area in central Colorado, mainly in Park County, between the Front Range and related mountains on the east and the Mosquito Range, Park Range, and Arkansas Hills on the west. On the north are the Continental Divide, the Kenosha Hills, and the Tarryall Mountains. On the south a low divide separates the Park from the valley of Arkansas River. The bordering mountains rise to maximum elevations of more than 14,000 feet, the average elevation of the Park being about 9,000 feet.

The geology of South Park has been only slightly studied by earlier workers. Since the Hayden Survey reports, the work of Washburne[3] on the South Park coal field has been the only one of much importance dealing with the Park itself, although several reports concerning adjoining areas in the mountains have appeared.

During the summers of 1930 and 1931 the writer studied the stratigraphy of the Mosquito Range for the United States Geological Survey. During the summers of 1932 and 1933 he spent considerable time with Don B. Gould working on the Pennsylvanian and Permian formations. In 1934 he was with a party from Northwestern University which made a study of the northern and northeastern parts

[1] Manuscript received, June 11, 1935.

[2] Associate professor of geology, Colorado School of Mines; assistant geologist, United States Geological Survey.

[3] C. W. Washburne, "The South Park Coal Field," *U. S. Geol. Survey Bull. 381* (1910), pp. 307–16.

of the Park. Most of the information contained in this report was obtained in connection with the 1934 work. The project was made possible by contributions from research funds of Northwestern University. Acknowledgment is gratefully given to the United States Geological Survey and Northwestern University for their assistance in the field work and to the Colorado School of Mines for the use of their laboratory facilities, and to Howard W. Miller, who was the writer's assistant.

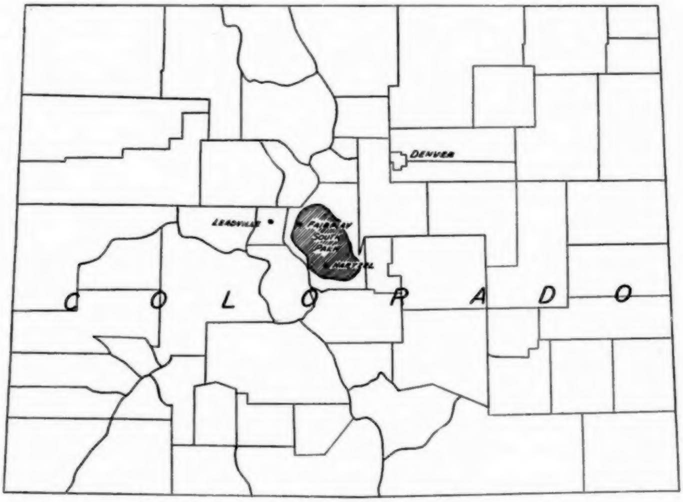


FIG. 1.—Map showing location of South Park, Park County, Colorado.

STRATIGRAPHY

The sedimentary beds exposed in the South Park region range in age from Cambrian to Pleistocene. The present paper, however, deals only with those of post-Pennsylvanian age, as the older beds crop out only along the edges of the mountains, beyond the area covered by the present work, and they have been described in a previous publication.[4]

Table I shows the formations present and their general character.

[4] J. H. Johnson, "The Paleozoic Stratigraphy of the Mosquito Range," *U. S. Geol. Survey Prof. Paper 185* (1934), pp. 15–43.

TABLE I

TABLE OF FORMATIONS RECOGNIZED IN SOUTH PARK

Age	*Thickness in Feet*	*Formation*	
Recent		Stream gravels, etc.	
Pleistocene		Glacial, glacio-fluvial, and stream deposits	
		Unconformity	
Tertiary	0–170	Lava flows and associated tuffs, etc. Lake beds	
		Unconformity	
?	3,500	Denver formation	Gravels, agglomerates, etc.
		Unconformity	
	0–375	Laramie formation	Sandstones, shales, tuffs, and coals
	0–350	Fox Hills sandstone	Sands and sandstones. A few calcareous and shaly sandstones at base
	2,200–2,600?	Pierre shale	Some sandy beds at top. Black papery shale. A few calcareous concretions and concretionary limestones
Cretaceous	500–540	Niobrara formation	Slaty calcareous shales. Limestones
		Unconformity	
	410–460	Benton shales	Sandstones and calcareous sandstones at top. Black shale alternating with bentonite streaks; some limestone and calcareous shales in upper third
	225	Dakota sandstone	Sandstones with beds and lenses of conglomerate; a few shales and sandy shales between sandstones on upper half
		Unconformity	
Jurassic	300	Morrison formation	Shales, calcareous shales, sandy shales, soft sandstones, siltstones; some limestones in lower half. Beds and lenses of fine conglomerate at some localities
Jurassic ?	5–60	?	Cross-bedded sandstone, red, pink, or cream-colored, ordinarily fine-grained. Some thin basal conglomerates. Beds containing grains of two distinct sizes observed at several localities. Locally, upper layers contain much calcareous cement
		Unconformity	
Permian and Pennsylvanian	0–5,000	Maroon formation	Red-beds: sandstones, and sandy shales, shales with beds of conglomerate, a few limestones, some of which are of algal origin. Some gypsum and possibly salt present west of Antero Junction

MAROON FORMATION[5]

Distribution.—Outcrops of the Maroon formation were found

[5] See also:

J. H. Johnson, *U. S. Geol. Survey Prof. Paper 185*, Pt. B (1935).

C. W. Henderson and others, "Colorado," *16th Internat. Geol. Cong. Guide Book 19* (1932), p. 11 (Pl. 2) and pp. 111–12.

Don B. Gould, "Stratigraphy and Structure of Pennsylvanian and Permian Rocks in Salt Creek Area, Mosquito Range, Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 7 (July, 1935), pp. 971–1009.

south of Hartzel and west of the Dakota hogback where they form most of the broad valley.

Character.—The formation consists mainly of red beds, sandstones, and sandy shales, with subordinate amounts of shale, conglomerate, and limestone. As a rule, the deposits are at least slightly arkosic or micaceous. They appear to have been formed chiefly of material derived from the erosion of pre-Cambrian rocks, although fragments of Paleozoic quartzites and limestones can be recognized here and there. Some of the upper beds contain pebbles of red sandstone. The color ranges from pink to bright red or brown. Some gray and greenish gray beds occur. The limestones are spaced irregularly throughout the series. A few limestones contain marine invertebrates; many, especially in the upper part of the formation, contain remains of calcareous algae; a few appear to be purely of algal origin.[6] Most of the limestones are fine-grained and massively bedded, and show conchoidal fracture. Some occur as concretionary masses or as nodules in shales and sandy shales. The color ranges from light to dark gray, a few are greenish gray, some are mottled. Almost all bleach to light gray on weathered surfaces.

The conglomerates occur as beds and lenses between the sandstones. They are most abundant in the lower part of the formation, but occur at intervals up to the top. Most of the pebbles are small (2 inches or less) and well rounded. However, some beds contain coarse material (up to 6 inches). Pebbles of quartz and other material from the pre-Cambrian predominate, although a few were observed which came from Paleozoic rocks. In many places the conglomerates show cross bedding.

Some gypsum and possibly some salt occur in the Red-beds west of Antero Junction, but none was observed within the area studied during the season of 1934.

Thickness.—In the vicinity of Fairplay the Maroon is believed, on the basis of rough estimates, to have a thickness of at least 5,000 feet, but no exact measurements have been made. Southwest of Hartsel the formation overlaps the pre-Cambrian and in one place (about east center Sec. 7, T. 12 S., R. 75 W.) only a few feet of sediments are present between the pre-Cambrian and the cross-bedded sandstone underlying the Morrison.

Age and general relations.—Fossils are scarce in the Maroon. The few marine invertebrates obtained have been poorly preserved, but belong to typical Carboniferous genera common in both the Penn-

[6] J. H. Johnson, "A Permian Algal Reef in South Park, Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 7 (July, 1933), pp. 863–65.

sylvanian and the Permian. The algae are undescribed types. Remains of the land plants have been found at several horizons at a number of localities and future search will probably yield many more. Near the base they appear to be of Pennsylvanian types, but for most of the formation they indicate a Permian age.

JURASSIC (?) SANDSTONE

At most localities a sandstone occurs below undoubted Morrison beds. It is in massive layers, is highly cross-bedded, and makes a good horizon marker. The thickness of this sandstone ranges up to 60 feet. In color it is red, pink, brown, cream, or white. Except for a basal conglomeratic phase, the sandstone is ordinarily sugary and medium-to-fine-grained. Some beds consist of quartz grains of two distinct sizes. It is questionable whether these beds are to be considered as basal Morrison or as an older Jurassic or Triassic deposit. According to Reeside,[7] they are not Jurassic and therefore they must be pre-Morrison. For the present they are tentatively classified as Jurassic (?).

MORRISON FORMATION

Areal distribution.—The Morrison formation forms narrow outcrops along the west side of the Dakota hogback from Hartsel to Red Hill. How much farther north it extends has not yet been ascertained. At several places faults have cut across the hogback and displaced the formation so that it appears locally on the east side of the ridge. At Hartsel the outcrop turns east-southeast and can be traced several miles until it disappears under float and Tertiary volcanics and sediments. Near the middle of the east half of Sec. 24, R. 76 W., T. 11 S., south-southeast of Garo, faulting has brought a small mass of Morrison into contact with Pierre shale. A typical outcrop was also observed about the center of the north part of Sec. 11, T. 12 S., R. 74 W. (old survey) about a mile west-northwest of Glentivar, just north of the Hartsel-Colorado Springs Highway; here the exposures are in a fault block, the Morrison or the underlying Jurassic (?) sandstone resting on the pre-Cambrian. Similar outcrops associated with faulting occur south of Kenosha Pass.

Character.—In general the formation consists of shales, limestones, siltstones, sandy shales, sands, sandstones, and local lenses of conglomerate. The lower half of the formation is light-colored, gray, white, green, and cream-colored; in the upper portions the beds are red, brown, mottled red and green, and yellow.

[7] J. B. Reeside, Jr., personal note.

Shales are the most important constituent of the Morrison. They are pure or slightly calcareous in the lower half of the formation, becoming more and more sandy in the upper beds. In color they are white, light gray, green, pale yellow, red, or dark brown.

Limestones occur only in the lower half of the formation. The beds range from 1 inch to about 2 feet in thickness. Nodular masses and irregular beds are common. Ordinarily the limestones are gray, but locally they show green, yellow, or chocolate tints. They are fine-grained and tend to have a conchoidal fracture.

Beds of mudstones or siltstones are found within the shales. They are fine-grained, break with a conchoidal fracture, and tend to assume nodular forms on weathering. Some are slightly calcareous. In color they are gray, green, yellow, brown, or red, ordinarily being about the same color as the enclosing shales. They are best developed near the base and just above the middle of the formation.

Sand and sandstones may occur within the formation, but they are most important in the upper third. The beds appear to be lenticular and show considerable variations, both in thickness and texture, within short distances. The sandstones are generally cross-bedded. In places they are conglomeratic; locally they are highly cemented or silicified.

The following section was measured along Highway 8 about 4.5 miles northeast of Fairplay in Sec. 12, T. 9 S., R. 77 W. The section affords a fair picture of the detailed character of the deposits.

	Thickness in Feet
Dakota formation	
Morrison formation	
Sandstone. Purplish red, fine-grained	2.3
Shale and sandy shale, dark purplish red	23.0
Sandstone and shaly sandstone. Red, fine-grained	13.0
Shales and sandy shales, green and greenish brown	15.0
Shale, greenish yellow, sandy	2.8
Sandstone. Fine-grained. Red and brown-yellow	9.5
Sandy shale, dark red, with streaks of green	12.0
Fine-grained soft sandstones alternating with sandy shales and shaly sandstone. Dark red, gray, and brown-to-yellow. Some shales green and mottled	24.0
Sandy shale, red, with streaks of green and yellow	18.0
Green mudstone	0.3
Sandstone. Fine-grained. Dark red and gray	9.8
Shale, dark purplish red, with thin streaks of dark gray, fine-grained sandstone	11.0
Partly covered, appears to consist mainly of shales and sandy shales. Red and purplish red, and mottled with green	102.0
Nodular limestone. Greenish gray. Conchoidal fracture	0.3
Shales, light greenish gray	15.0
Limestone, gray, contains algal tubes	0.8
Shale, gray-to-green, calcareous	6.2
Limestone, gray, contains abundant small glassy tubes	0.9
Shale, gray-to-greenish gray. Slightly calcareous	8.6
Limestone, gray-to-greenish gray	0.5
Gray shale, slightly calcareous	3.4
Dark gray limestone. Contains many glassy tubes	2.1

Shale, slightly calcareous. Light gray-to-green	5.0
Gray limestone, algal tubes and small gastropods	0.4
Calcareous shale, dark green-gray	4.2
Muddy limestone, yellow-brown, with concentric fracture	1.5
Massive gray limestone. Traces of algal tubes and small gastropods	1.7
Calcareous shale, light gray	9.0
Muddy limestone. Yellow-brown. Effervesces freely with acid	0.3
Shale, red to green, sandy and calcareous	2.0
Gray limestone, conchoidal fracture, contains glassy tubes, and cross sections of gastropods	1.5
Gray, calcareous shale. Streak of greenish shaly limestone near top	4.3
Limestone, gray, weathers nodular. Glassy algal tubes	0.7
Calcareous shale, gray	0.9
Limestone, gray, conchoidal fracture. Contains a few algal tubes	0.9
Shale, greenish gray, sandy	3.8
Limestone, gray, massive. Conchoidal. Contains a few glassy algal tubes and cross sections of small, low-spired gastropods	1.2
Calcareous shale, mottled green and red	1.6
Limestone, gray, conchoidal fracture	0.3
Shale, only slightly calcareous, red	1.7
Limestone, massive, gray, contains glassy algal tubes	1.0
Calcareous shale, mottled red and green	1.2
Limestone, gray, conchoidal fracture. Suggestion of a few glassy algal tubes	0.5
Calcareous shale, mottled dark red and green	0.8
Limestone, slightly muddy (effervesces freely). Mottled red and brown, weathers buff	0.3
Calcareous shale, light green and brown	1.0
Sandy calcareous shale, dark red	1.8
Dark red shaly sandstone	2.0

Thickness.—The thickness of the Morrison formation shows considerable variation at the different localities. This may have resulted from differences in the original deposition, or from irregular pre-Dakota erosion, or from both causes acting together. In any case, the second cause is believed to have been the more important, as variations in thickness appear to affect mainly the upper half of the formation. An average of measurements taken gives a thickness of about 300 feet.

Age and general relations.—In the area studied the only fossils found in the Morrison were fragments of bone, cross sections of small low-spired gastropods, and glassy tubes of calcareous algae. The forms represented by the bone and gastropod fragments were not determinable. The algal tubes belong to *chara*-like forms similar to those found in the Morrison along the Front Range.

Along the Dakota hogback the formation rests either on the Jurassic (?) sandstone or unconformably on the Red-beds of the Maroon formation and is unconformably overlain by the Dakota sandstone. Along the eastern rim of the Park the Morrison appears to overlap on the pre-Cambrian, but additional field work will be necessary to conclusively establish the fact. On the basis of information obtained in adjoining regions, the Morrison is considered to be of Upper Jurassic age.

DAKOTA FORMATION

The distribution of the Dakota formation is practically the same as that of the Morrison formation. The best outcrops are to be found along the Dakota hogback. This is a prominent ridge extending from the west side of Little Baldy Mountain southward to Hartsel. Small outcrops were observed along the eastern rim of the Park from the vicinity of Kenosha Pass northward, and small patches of the formation are included in fault blocks north, northwest, and west of Spinney Mountain. Originally the formation evidently formed continuous outcrops along the eastern rim of the Park but these have been largely destroyed or concealed by erosion, thrust faulting, volcanic activity, and the deposition of later formations. Probably the Dakota underlies much of the Park.

General characteristics.—In most localities the Dakota consists essentially of sandstones. These are generally soft, only a few of the layers being firmly cemented. Locally, however, the whole formation has been altered to quartzite. The sandstones are ordinarily white or light gray, weathering to buff or yellowish brown. They are thin-bedded to medium-bedded. Cross-bedding is common. The sandstones consist predominantly of quartz sand, although some of the beds are slightly arkosic. Streaks and lenses of conglomerate occur in the sandstones. The pebbles of the conglomerates are smooth and well rounded. They consist mainly of quartz, but in the lower layer of the formation, many clay balls and fragments of limestone and mudstone from the Morrison formation were observed.

Near the middle of the formation a few layers of shale and sandy shale occur locally. These are black-to-dark gray. At Red Hill, and near Garo, they include white clays and light gray-to-pink sandy shales. The harder layers make the ridges along the outcrops, but the same bed does not form the crest of the ridge along the entire length of the Dakota hogback, the ridge crest stepping back and forth from layer to layer.

The following section, measured along the highway in T. 9 S., R. 77 W., shows the detailed character of the formation.

	Thickness in Feet
Benton shales	
Dakota formation	
Sandstone, massively bedded, gray, weathering light brown. Bedding surfaces coarsely rippled, and showing some casts of fucoids. Upper layers contain suggestions of worm borings	11.0
Sandstone, thinly bedded. Surfaces rippled, and marked by casts of large fucoids; one layer shows suggestions of sun cracks	6.0
Sandy shale, gray-to-dark gray	4.5
Soft sandstone, massively bedded, light yellow-gray, weathers brown	10.0
Sandstone, thinly bedded, soft, white-to-tan, weathering brown and purplish	13.0
Soft, friable sandstone, pure, well rounded sand, well sorted. Massive. Cross-bedding near top. White-to-tan, streaks of purple and pink on weathering.	21.0

Sandstone, white-to-cream-colored. Soft, thinly bedded. Coarse fucoid marking on some bedding planes	9.0
Soft sandstone, light brown, stained pink. Dark gray shale	3.6
Sandy shale, dark gray	2.2
Soft sandstone, slightly cross-bedded. Light red-brown-to-cream-colored. Streaks and breaks of small pebbles and mud balls	16.0
Conglomeratic sandstone, pebbles of gray quartz as large as 0.25 inch, and a light-colored material	0.3
Soft sand and sandstone. Light yellow-brown	15.3
Fine gray sandstone and shaly sandstone. Light, contains some small fragments of carbonized plants	2.0
Soft sandstone, light gray weathering brown and reddish	14.0
Dark gray sandstone and sandy shale capped with thin, slightly calcareous sandstone	11.0
Sandstone, fine-grained. Soft, disintegrates easily to soft sand. Cream-colored with pink and blue-gray bands and layers	53.0

Thickness.—The thickness varies slightly in the different sections measured but seems to average about 225 feet.

Age and general relations.—The only fossils obtained from the Dakota formation in this area were some poorly preserved leaves and casts of stems of land plants. None were determinable, but by analogy with adjoining areas where the formation has been studied it is assumed that the Dakota has an early Upper Cretaceous age.

BENTON SHALE

Areal distribution.—Good outcrops of the Benton shale are few. The formation is soft; consequently, most outcrops are covered with vegetation. Theoretically, it should crop out along the east side of the Dakota hogback and west of the Dakota at several places along the east side of the Park. Actually the only good outcrops observed were along Platte River southeast of Garo, in T. 11 S., R. 76 W., southeast of Glentivar in the NW. $\frac{1}{4}$, Sec. 24, T. 12 S., R. 74 W., in a fault block north-northwest of Glentivar nearly in the center of the north part of Sec. 11, T. 12 S., R. 74 W., and in another fault block in the north-center of Sec. 35, T. 12 S., R. 74 W. Fair-to-poor outcrops occur on the west side of an intrusion about 2 miles north of Jefferson; here, however, the beds have been slightly metamorphosed so that their appearance and character are not typical.

Character.—The Benton formation consists mainly of black shales; some sandstones, limestones, and bentonite beds are, however, included.

The shales are normally black and papery. In places isolated crystals and thin veins of gypsum occur in the shales. The sandstones are usually thin and highly calcareous. Many of them have a fetid or petroliferous odor. They occur at irregular intervals throughout the formation. The best development of sandstone, however, is at the

top, where 11 to 20 feet of calcareous sandstones occur. This upper sandstone corresponds approximately with the sandstone in the Carlile shale at the north edge of the Pueblo Quadrangle.

The limestones are ordinarily fine-grained and dark gray-to-black, but bleach to light gray or light yellowish gray on weathering. Some of them are shaly. The best development of limestone occurs in a zone about 50 feet thick, commencing about 90 feet below the top of the formation. Almost all of the limestones and calcareous shales of the formation are restricted to this zone, which corresponds in a general way with the Greenhorn limestone of the Pueblo region.

The limestones of the Benton become better developed in a southeasterly direction across the Park; thus, near Garo there is only one well developed limestone and some shaly limestone beds, but in the fault block northwest of Glentivar there are several distinct limestone layers alternating with calcareous shales.

Bentonite occurs as thin beds at intervals throughout the formation. On detailed study these beds are much more numerous than would be supposed on casual observation. They range in thickness from very thin streaks to a maximum of more than 2 feet. In the thicker beds the proportion of bentonite is less.

The following section, measured by J. H. Johnson and H. W. Miller, on the Platte River in T. 11 S., R. 76 W., nearly 1.5 mile below the town of Garo, shows the detailed character.

Niobrara formation Benton shale	*Thickness in Feet*
Sandstone, dark gray, weathering brown. Considerable calcareous cement. Upper foot highly calcareous and contains shell fragments and fossils (*Ostrea lugubris*, large pelecypods, a *Gryphaea* cephalopod of the genus *Prionocyclus*, fucoid casts, and shark teeth)	11.0
Black shale	14.6
Bentonite	0.2
Black shale	3.6
Bentonite	0.3
Black papery shale	17.0
Bentonite	0.1
Black papery shale, a few secondary gypsum crystals	29.0
Bentonite	0.2
Black papery shale	1.4
Limestone, dark gray, weathers white	0.9
Black shale, streaks of calcareous shale	18.0
Bentonite	0.1
Black shale	2.8
Bentonite	0.8
Black shale	4.8
Bentonite	0.1
Black shale	2.8
Bentonite	1.1
Black papery shale	2.0
Streak of bentonite	0.1
Black shale, slightly calcareous	5.7

Niobrara formation Benton shale	*Thickness in Feet*
Bentonite	0.2
Black shale	1.9
Bentonite	0.1
Black shale	9.7
Bentonite	0.1
Black shale	13.0
Calcareous shale, slaty, dark gray, weathering yellowish white	3.4
Limestone	1.2
Calcareous shale, slaty	0.8
Bentonite	0.3
Calcareous shale and shaly limestone	1.0
Black shale	7.8
Bentonite	0.2
Calcareous shale	2.8
Bentonite	0.1
Black shale	6.5
Bentonite	0.1
Calcareous shale	4.8
Bentonite	0.1
Black shale	6.3
Gray calcareous shale	4.5
Bentonite	0.2
Black shale	5.8
Limestone, slightly sandy, gray. Contains many fish teeth, pieces of bone, carbonized wood fragments, pieces of pelecypod shells, and casts of an ammonite. Petroliferous odor from fresh fractures	0.7
Bentonite	2.3
Black shale	2.9
Bentonite	0.2
Black shale	8.8
Bentonite	0.6
Sandy limestone with fragments of pelecypod shells	0.1
Black papery shale	19.2
Sandy limestone with shell fragments	0.1
Black shale	3.5
Bentonite	1.4
Black shale	7.8
Sandy limestone	0.1
Black shale	63.0
Impure bentonite	2.7
Black shale	1.8
Calcareous sandstone	0.7
Bentonite fairly pure	3.1
Black papery shale	3.2
Bentonite	0.1
Black papery shale	2.4
Bentonite	0.3
Black papery shale	4.0
Bentonite	0.2
Black papery shale	11.2
Bentonite and gypsum	0.4
Black papery shales	1.3
Bentonite (altering to gypsum)	0.2
Black shale	19.0
Covered to Dakota; appears to be black shale	55.0

Thickness.—The Benton ranges in thickness from 410 to 460 feet in various parts of the Park. A section measured at Red Hill showed 450 feet to be present; along Platte River 414 feet were observed.

Age and relations.—Fossils are abundant in the upper sandstones and in a few of the limestones. Fairly large collections were obtained at several localities. The forms include pelecypods, gastropods, cephalopods, and fish teeth, bones, and scales. The small frilled oyster, *Ostrea lugubris*, is the distinctive index fossil for the upper sandstone. *Inoceramus labiatus* ranges throughout the entire Benton, but is most common in the limestone zone. Ammonites of several genera were obtained.

The fossils indicate that the beds belong to the Benton shale, the older formation of the Colorado group of the Upper Cretaceous. The fauna is the same as that found in beds of Benton age in the Pueblo Quadrangle and in the Huerfano basin.[8]

The Benton appears to rest conformably on the Dakota. There is probably an unconformity separating it from the overlying Niobrara.[9]

NIOBRARA FORMATION

Areal distribution.—The Niobrara crops out along the eastern side of the Dakota hogback and in a few fault blocks along the southeastern side of the Park. The best outcrop for study is along the Platte River about 2 miles below Garo where the stream has undercut steeply dipping beds producing bare cliffs of considerable height. A small exposure of the middle part of the formation may be seen along the highway between Fairplay and Como near the east side of Red Hill hogback.

General character.—The Niobrara consists of two divisions: a lower consisting of limestone and an upper consisting mainly of calcareous shales. The lower member is thin and is made up of light gray, slightly chalky limestones which weather white or pale yellow. The beds range from a few inches to more than a foot in thickness, and the limestone is ordinarily pure.

The upper member is made up of dark gray-to-black calcareous shales which weather light gray or pale yellow and ordinarily form yellow soil. When fresh, the material is hard and platy.

Thickness.—The average thickness of the formation is about 540 feet; the limestone includes only 40–60 feet, the upper shale member comprising the greater part.

Age and relations.—The Niobrara formation is separated from the underlying Benton by an unconformity. This is ordinarily shown by the presence of an indurated sandstone or fine conglomerate which

[8] T. W. Stanton, "The Colorado Formation and Its Invertebrate Fauna," *U. S. Geol. Survey Bull. 106* (1893).

[9] J. H. Johnson, "Unconformity in the Colorado Group in Eastern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 6 (June, 1930), pp. 789–94.

locally contains numerous fish teeth.[10] Fossils occur sparingly throughout the formation. The characteristic fossil of the lower division is *Inoceramus deformis*. *Ostrea congesta* is found throughout the formation, both as single shells and in congested colonies and clusters. Fragments of large *Inoceramus* are common. *Foraminifera* are plentiful throughout the formation. These fossils are the same as those which occur in the formation in other parts of the state. The Niobrara forms the upper division of the Colorado group of the Upper Cretaceous. The formation grades upward into the Pierre through a series of transition beds.

PIERRE SHALE

Areal distribution.—The Pierre shale forms broad outcrops along the valley of Trout Creek on the eastern side of the Dakota hogback from the crest of the highway on Red Hill southward. Another large outcrop occurs farther east, extending south from Como for 15 or 16 miles between the Basin Ridge and the more recent deposits which cover the eastern side of the park.

Character.—The formation consists essentially of black fissile shale; but there are some sandy and calcareous beds. The shale is ordinarily very black and papery near the base. Near the top some gray shales occur.

Numerous zones and bands of calcareous concretions and local thin limestones occur between the shales. The concretions are as much as 4 feet in diameter, but most of them are considerably smaller. Some of them are very fossiliferous.

The sandy layers are ordinarily fine-grained and range in color from a dark gray to a rather light brownish gray. Sandy zones occur near the base and again near the top of the formation. They are best developed near the top, where several hundred feet of sandy shale and shaly sandstone occur. At a locality or two visited there appears to be a gradual transition upward into the sandstones which have been called the Fox Hills formation.

Thickness.—Accurate determinations of the thickness of the formation have not been made, but it is estimated to range from about 2,200 to 2,500 feet in thickness.

Age and general relations.—Fossils are abundant at certain horizons, especially in the limestone beds and calcareous concretions. These include pelecypods (especially of the genus *Inoceramus*), gastropods, and cephalopods. Here and there remains of fishes were also observed.

[10] J. H. Johnson, *op. cit.*

The Pierre seems to rest conformably on the Niobrara below and to grade upward into the Fox Hills above without stratigraphic break. It is the lower division of the Montana group of the Upper Cretaceous.

FOX HILLS SANDSTONE

Areal distribution.—The Fox Hills sandstone crops out along the eastern side of the South Park coal basin east of Como and again along the small anticline 5 or 6 miles north of Hartsel. Good outcrops are scarce, as they are generally covered by sod or gravel deposits. Only two good outcrops were noted during the present work, one just west of the King mines in Secs. 2 and 12, T. 9 S., R. 76 W., and the other along the anticline mentioned in Sec. 21, T. 11 S., R. 75 W.

General character.—Ordinarily the formation consists of fairly pure, fine-grained sandstones. They are lightly cemented, some beds consisting practically of loose sand. The color is white, light gray, yellow or brown, orange-brown being the most common. Near the base some of the beds are shaly; higher, some are moderately calcareous. Cross-bedding is common and is in many places very well developed.

The following section measured just west of the King mines in Secs. 2 and 11, T. 9 S., R. 76 W., illustrates the detailed character of the formation.

Laramie formation Fox Hills sandstone	*Thickness in Feet*
Largely covered, apparently soft yellowish brown sand	47.0
Sandstone, fine-grained, highly cross-bedded, yellow-to-brown. Contains some pelecypods and casts of *Halymenites major* and small carbonized fragments of leaves, wood, and stems	55.0
Sand, soft, yellowish gray	18.0
Sandstone, slabby, gray, calcareous. Highly fossiliferous, bearing marine pelecypods and gastropods	6.0
Sand and sandy shale, soft, gray-to-yellow. Outcrops poor, largely covered	40.0
Shale and sandy shale, dark grayish brown	180.0
Brown sandstone, micaceous, and slightly arkosic. Suggestions of pelecypod casts	16.0
Soft sandy shale and shaly limestone, containing numerous small flakes of mica. Color, light brown. Beds transitional, to the Pierre	110.0
Black papery shale, definitely Pierre	

Thickness.—The formation reaches a maximum of about 350 feet. In most places less is present, and it appears that varying amounts were eroded by post-Cretaceous, pre-Denver erosion in many places; locally, the formation was completely removed.

Age and relations.—Fossils are relatively scarce in the Fox Hills; however, in most localities a careful search brings a few to light. The supposed algal form, *Halymenites major*, is the characteristic fossil of the formation in this region. Several marine fossils, mainly pelecypods

and gastropods, were obtained from some of the slightly calcareous sandstones about the middle of the formation. These consist of forms which are known from the Fox Hills east of the Front Range. The Fox Hills forms the upper part of the Montana group of the Cretaceous. It rests conformably on the Pierre and grades upward into the Laramie (?) formation without apparent break.

LARAMIE (?) FORMATION

Distribution.—The beds that are tentatively correlated with the Laramie formation of the Denver basin crop out in only limited areas. The largest outcrop occurs as a long, narrow, north-south strip east of Como. It is about 6 miles long, extending from Sec. 23, T. 9 S., R. 76 W., northward to Sec. 23, T. 8 S., R. 76 W. The shale probably extends farther north, but is covered by recent and Tertiary alluvial deposits. A small strip occurs along the west edge of the town of Como, and a third, about a mile long, has an east-west trend in Sec. 21, T. 9 S., R. 76 W. Narrow outcrops occur also farther south in T. 11, R. 75 W. The outcrops are poor, being largely covered by vegetation and loose material.

Character.—The Laramie consists of sandstones, shales, volcanic tuffs, and coal. The sandstones are white-to-dark gray. They ordinarily consist of white sandstone of medium-to-fine texture with considerable included carbonaceous material. Many are cross-bedded and some layers show worm borings in large numbers. Variable in detail, the bedding generally tends toward massive lenticular beds. The shales range in color through various shades of brown and gray to black. Many of the shales are sandy. Some beds of water-laid volcanic material occur within the formation, particularly in the upper half.

Three coal beds are known in the Laramie (?) formation. The lowest occurs immediately above the basal sandstones and was reported to be the best commercial coal; it attains a thickness of 6–10 feet, averaging about 8 feet at the King mines. The second seam occurs 180–187 feet above the first, and was mined in several places; its thickness varies from 1.5 to 4 feet. A third bed is about 220 feet above the first;[11] at King it is said to be about 4 feet thick. Some mines were opened along the third seam in the vicinity of Como and King.

The following section was measured at King in Secs. 2 and 11, T. 9 S., R. 76 W. It includes only the lower part of the formation, but will serve to show the general character.

[11] C. W. Washburne, "The South Park Coal Field," *U. S. Geol. Survey Bull. 381* (1910), pp. 307–16.

	Thickness in Feet
Brown sandstone, finely granular, somewhat micaceous	24.0
Coal Number 1	7.5
White sandstone, sugary, some beds rather coarse-grained, others medium-to-fine-grained. The coarser beds are slightly micaceous and arkosic. Thin-to-medium-bedded. Some bedding planes show ripple marks measuring 5–6 inches from crest to crest with some fucoid casts and worm borings. Casts and carbon impressions of plant stems abundant in some layers	6.0
Sandstone, soft, slabby, brown-gray. Medium-to-fine-grained. Some breaks of sandy shale, finely micaceous, and slightly arkosic. Partly covered. Outcrops poor	28.0
Fox Hills sandstone	

Thickness.—The thickness of the formation varies greatly. A maximum of nearly 375 feet occurs in the vicinity of King. From that maximum figure the thickness ranges down to zero. There may have been differences in the amount originally deposited, but considerable though varying amounts of the formation were eroded away before the deposition of the overlying Denver (?) formation, and the great variations in thickness are to be explained largely by this erosion.

Age and general relations.—To date but few fossils have been obtained from these beds in this region. During the season of 1934 some well preserved leaves were obtained from a fine-grained tuff between the second and third coals, but as yet the species have not been determined.

The formation appears to rest conformably on the underlying Fox Hills formation, for although there is lithologic change, no definite evidence of an unconformity was observed. It is separated from the overlying Denver (?) formation by an unconformity which represents an interval during which erosion was active, and during which time some uplift and deformation occurred, followed by vulcanism. The relations between the Laramie (?) and the overlying Denver (?) are, however, as yet not thoroughly understood. Work is in progress looking toward clarification.

It is assumed that the Laramie (?) formation of the South Park region correlates, at least approximately, with the Laramie of the Denver basin, but evidence for exact correlation is lacking.

DENVER (?) FORMATION

Distribution.—The deposits tentatively correlated with the Denver formation cover large areas along the northeastern side of the Park. The largest area of outcrops, partly covered by alluvium, is nearly 23 miles long and as wide as 2.5 miles in places.

Character.—The beds consist of conglomerate, gravel, grit, and sandstones with interbedded volcanic tuffs and agglomerates. The sediments were derived mainly from the pre-Cambrian, granite

pebbles and boulders being very common. In most places, though not everywhere, the material is well rounded; locally it is surprisingly coarse. Boulders as large as 4 or 5 feet in diameter have been observed at several localities. Apparently the material was derived from the west, as the cross-bedding dips eastward.

Volcanic tuffs and agglomerates occur at intervals throughout the series. Generally they are light-colored. They range from thin beds of fine volcanic ash to thick layers of coarse fragmental material which has been more or less reworked.

Thickness.—No careful measurements of the thickness have been obtained, but there is no question that the formation attains considerable thickness. At least 3,000 feet of beds are present at several localities. It is estimated that a maximum of nearly 8,000 feet is attained east of Como.

Age and general relations.—The Denver (?) formation is believed to rest unconformably on the Laramie (?) sediments, although the exact relations are not clear at present. In the northern part of the Park the Denver (?) forms the surface rock where not covered by alluvium. In the southern part the Denver (?) formation is overlain by volcanic rocks, lake beds, and stream deposits ranging in age from the Middle Tertiary to the present.

The only fossils obtained from the Denver (?) beds are the leaves of land plants and an abundance of silicified wood. The leaves are mainly from trees very similar in appearance to modern types. The fossils determined indicate an age approximately equivalent to the Denver formation of the Denver basin; that is, early Eocene.

TERTIARY LAKE BEDS

Areal distribution.—Tertiary lake beds were found at several localities along the southern and east-central sides of the Park. In general, the exposures are poor, as the material is soft and easily eroded; however, several good outcrops were found. The best of these forms cliffs along the east side of a small valley in Sec. 30 S., T. 13 S., R. 75 W. Another very good outcrop is in the SW. $\frac{1}{4}$, Sec. 36, T. 12, R. 76 W. The northernmost outcrop observed was along the Como-Hartsel road in the SW. $\frac{1}{4}$, Sec. 23, T. 10 S., R. 75 W.

Character.—The beds consist of shales, sandstone, water-laid volcanic tuffs, calcareous shales, and limestones. Much of the limestone is of algal origin. At a few localities, basal conglomerates and lenses of conglomeratic material were observed. Locally, volcanic ash and other fine volcanic material are present in large amounts. Silicification has occurred on a large scale, with the result that many of the beds

are highly altered, the limestones sometimes being almost completely changed to masses of white chert or translucent chalcedony, and even the shales are in places altered to a highly vitrified rock. Silicification seems to have occurred almost everywhere close to the shore lines of the old lake. This alteration has not only produced some peculiar kinds of rock, but in places has made it very difficult to determine the exact character of the original material. At one locality a limestone bed was traced along the strike for a distance of nearly 0.75 mile, during which it changed from an almost pure algal limestone, showing structure excellently, into a porous cherty rock full of chalcedonic masses and showing no suggestion of the original structure.

Thickness.—The outcrops studied show thicknesses ranging from a few feet to more than 200 feet. In general, the exposures are so poor that it is difficult to obtain an accurate idea of the thickness.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL 19, NO. 9 (SEPTEMBER, 1935), PP. 1357-1388, 4 FIGS.

AREAL GEOLOGY OF EOCENE IN NORTHEASTERN MEXICO[1]

WILLIAM G. KANE[2] AND GUY B. GIERHART[3]
Saltillo, Coahuila, and Corpus Christi, Texas

ABSTRACT

The Eocene contacts as they appear along the Rio Grande in Texas have been traced southward into Mexico as far as the Rio San Juan. The nomenclature and contacts used are with slight modifications the same as those at present accepted by the United States Geological Survey. A stratigraphic reconnaissance has been made which correlates some of the results of several rather extensive and detailed mapping operations carried on by the writers during the past 7 years.

Cross sections at six places along the belt covered by the outcrop of these beds reveal a progressive thickening toward the south of the Midway and Wilcox sections exposed. The Carrizo sandstone is shown to be thickening rapidly toward the south as far as the Monterrey-Laredo railroad from which point a marked thinning is noted toward the south. The Mount Selman becomes much thicker toward the south and is characterized by more sandstone beds than it has in the border province of Texas. The Yegua and Fayette formations also have more sandstones here than in Webb and Zapata counties, Texas, but these begin to thin toward the south and many of them disappear before the Rio San Juan is reached.

For convenience in locating the contacts and making a study of the excellent sections exposed, distances in miles and in kilometers are given in connection with some of the stratigraphic sections traversed by roads or railroads. Paleontologic studies of surface samples and well cuttings made on the basis of Texas type sections seem generally to corroborate the position of the contacts carried down by geologic mapping.

INTRODUCTION

The region dealt with in this paper lies on the Mexican side of the Rio Grande and extends from the vicinity of Guerrero, Coahuila, on the north, to the Rio San Juan and the Matamoras-to-Monterrey railroad line on the south. The belt covered by outcrops of Eocene Tertiary beds within this region is 150 miles long and reaches its maximum width of 50 miles at its south end.

During the past 5 years large areas of the region have been mapped in detail by the Cia. Petrolera Tamaulipas, S. A., and the Ohio-Mexico Oil Corporation. This paper represents an attempt to correlate the areal geology mapped by these two companies and to augment it with such other work as was necessary to tie it into the Texas section as described along the Rio Grande by A. C. Trow-

[1] Manuscript received, August 5, 1935. Read before the Association at Houston March 25, 1933.

[2] Chief geologist, Ohio-Mexico Oil Corporation.

[3] Geologist, Humble Oil and Refining Company.

bridge, J. T. Lonsdale, and others. The writers wish to express their gratitude to the managements of both the companies named for permission to publish this work. Credit is also due to A. H. Petsch and Sherman Leonard of the Ohio-Mexico Oil Corporation, and L. P. Teas and H. C. Vanderpool of the Humble Oil and Refining Company for much of the detailed work done in the field in connection with the mapping of these areas. Valuable assistance in placing the location of the contacts of the Midway, Indio, and Carrizo formations north of the Laredo-Monterrey railroad was given by H. Nielson, P. Keeley, and W. B. Allen, geologists for the Mexican Gulf Oil Company. The writers are also indebted to these men for some of the measured thicknesses used in this part of the area.

Up to the present time there have been only two publications[4] in the scientific literature dealing with the areal geology of the Eocene Tertiary sediments of this part of Mexico.

While both of these papers attempted to give the areal geology of the region, much of the work was predicated on long range correlations of beds on the basis of lithologic similarity, and, as a result, many of the contacts given are not in accord with the views of the present writers.

In Dumble's paper the only Eocene contact which is approximately the same as that drawn in the present work is the Cretaceous-Midway contact at its base. Even this contact is believed to be in error when he brings it as far west as Azulejos, Rancho del Pescado, and a point near Roderiguez on the Rio Salado. Azulejos is nearly 15 miles west of this contact, while Rancho del Pescado and Roderiguez are both more than 10 miles west of it. From the Rio Salado toward the south, Dumble seems to have traced this contact as far as the Rio San Juan with accuracy, but, as will be pointed out, his observations regarding Wilcox and Carrizo overlaps along this contact are still open to question. Dumble's contacts for all of the other beds of the Eocene, at least as far south as the Rio San Juan, have long since been discarded.

While Tatum's paper gives a valuable comprehensive survey of the general geology of northeastern Mexico, it differs in many important respects from the findings of the present investigation.

Kellum[5] has pointed out the fallacy of trying to project the ef-

[4] E. T. Dumble, "Tertiary Deposits of Northeastern Mexico," *California Acad. Sci. Proc.* 5, No. 6 (1915).

J. L. Tatum, "General Geology of Northeast Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 8 (August, 1931).

[5] L. B. Kellum, "Structure of the San Carlos Mountains, Mexico," *Bull. Geol. Soc. America* (abstract), Vol. 42, No. 1 (March, 1931).

fects of the Tamaulipas arch northward into the Zacate district by showing that the axis of the San Carlos Mountains extends east and west rather than north and south. On the other hand, it seems unlikely that the effects of the Salado arch can be projected southward into the Aldamas area without ignoring such important features as the Vallecillo anticlinal axis. North of the Rio San Juan, moreover, there are several structural features of striking geologic significance which have not received consideration that was commensurate with their importance. The La Presa anticline with its 350 feet of closure, the Palo Blanco syncline with its several hundred feet of closure and the Rancherias structure with more than 500 feet of reversal are three geologic factors that rank in importance with any structural feature found in the Eocene province of Mexico. Two of these anticlines are the only structures in northeastern Mexico from which commercial production has been obtained to date.

The areal geology of Tatum's paper is corroborated only in that part of the region covered by Midway, Wilcox, and Carrizo beds. His location and description of the Cretaceous-Tertiary contact with its numerous fossil localities is accurate. His locations and descriptions of the beds of the Wilcox and Carrizo, predicated as they were on the actual tracing of the Carrizo sandstone escarpment, from the Rio Grande down into Mexico, are also correct in every particular. From this point upward in the section, however, his areal geology was based on lithologic comparisons made of beds in the Zacate district south of the Rio San Juan in Mexico with supposedly similar beds in LaSalle and McMullen counties, Texas, more than 100 miles away. As a consequence of this attempted long-range correlation without the benefits of paleontology or continuity as a guide, his contacts of the formations above the Carrizo do not all agree with the contacts as placed by the present writers. Certainly his whole conception of the subdivision of the Upper Eocene must be considered to be at variance with the generally accepted version of this section as used by the United States Geological Survey, the Bureau of Economic Geology of the University of Texas, and almost all of the petroleum geologists familiar with the stratigraphy of Webb, Zapata, and Starr counties, Texas.

All of the contacts shown on the map (Fig. 1) presented with this paper except those shown by a broken line have been actually traced on the ground from known and generally accepted contacts along the Rio Grande in Texas. The subdivisions of the Eocene used in this work are as follows.

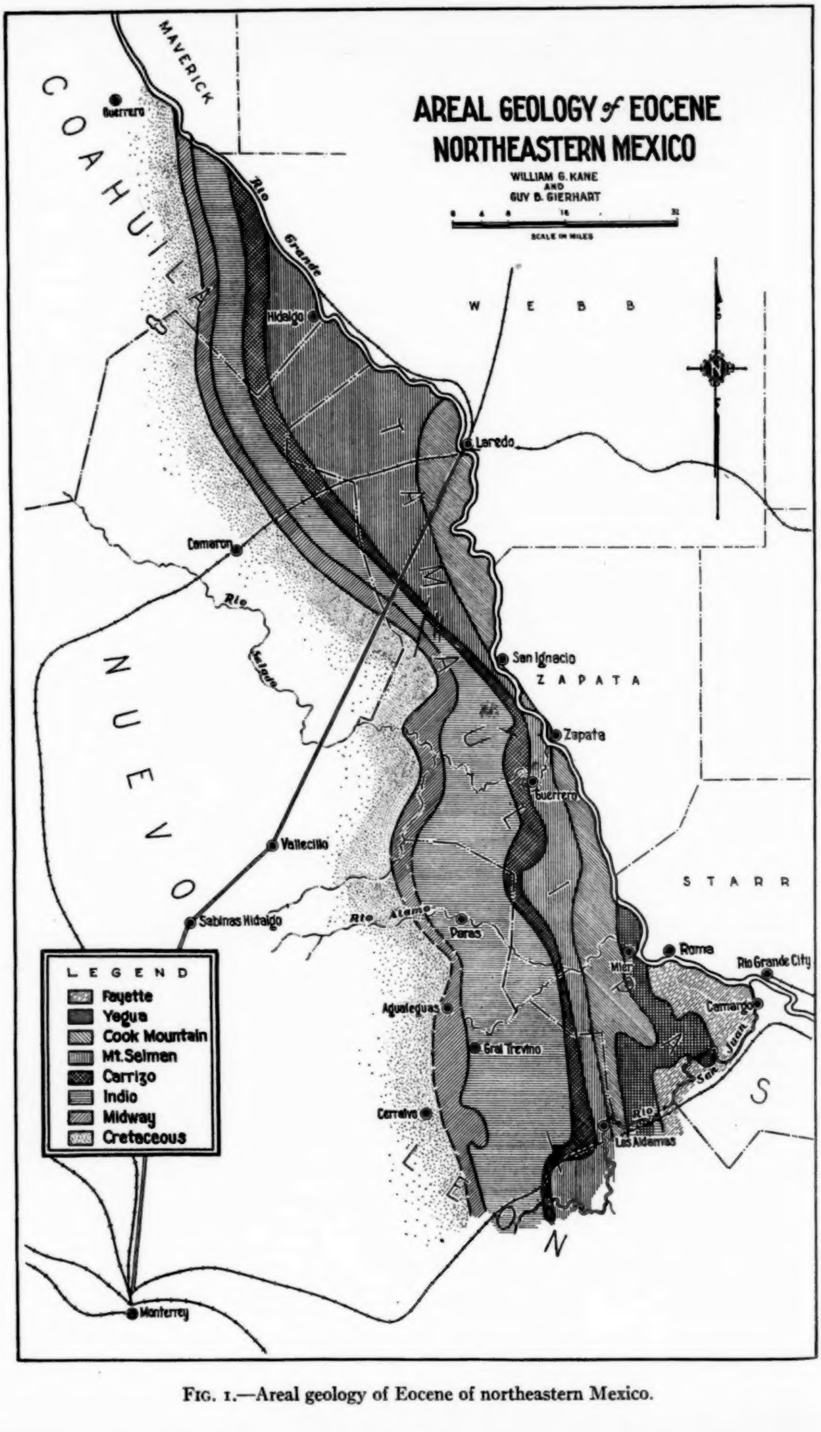


FIG. 1.—Areal geology of Eocene of northeastern Mexico.

Jackson	Fayette	
Claiborne	Yegua	
	Cook Mountain	
	Mount Selman	Upper Mount Selman
		Bigford member
	Carrizo	
Wilcox	Indio	
Midway	Midway	

This system of nomenclature appears to be most acceptable to a large majority of geologists working in southwest Texas and is the same as that used by Alexander Deussen[6] except for his inclusion of the Carrizo sandstone in the Wilcox group.

It should be noted, however, that this subdivision has made several departures from the nomenclature used in the 1932 preliminary edition of the *Geologic Map of Texas* by the United States Geological Survey[7] and the revised edition of Trowbridge's bulletin[8] on the geology of the lower Rio Grande region of Texas. The three most important points of departure are noted as follows.

1. The Bigford formation of Trowbridge and the United States Geological Survey has been considered as the basal member of the Mount Selman formation.

2. The Cockfield formation of Trowbridge and the United States Geological Survey has been called the Yegua formation.

3. The position of the bottom of the Fayette formation has been moved downward a short distance in the section and therefore westward from the point where Trowbridge shows it on his mapping near Roma, Starr County, Texas.

Since practically all of the micropaleontologists who have worked on this part of the Eocene section are agreed that the clay shales beneath the Roma sandstone are still of Fayette age and that the first typical Yegua *Foraminifera* (*Eponides yeguaensis*) is found beneath the sandstone which is exposed along the Rio Grande downstream from Salineno, Starr County, Texas, the writers place the bottom of Fayette at the base of this Salineno sandstone.

In order to present a comprehensive picture of the stratigraphy of this region a composite description of all of the formations is given and an attempt is made to show the special characteristics of each formation as it appears in the various localities. It is noted that some of the best exposures of the lower part of the section were

[6] Alexander Deussen, "Geology of the Coastal Plain of Texas West of Brazos River," *U.S. Geol. Survey Prof. Paper 126* (1924).

[7] *Univ. Texas Bull. 3232*, "The Geology of Texas," Vol. I, Plate XI.

[8] A. C. Trowbridge, "Tertiary and Quaternary Geology of the Lower Rio Grande Region, Texas," *U.S. Geol. Survey Bull. 837* (1932).

found in the banks of the Rio Grande. Excellent descriptions of these sections along the American side of the river, as well as complete listings of all the fossils found in them, may be found in Stephenson's Cretaceous-Eocene contact studies of 1914[9] and in the two Trowbridge reports.

To supplement the information obtained along the Rio Grande and in the areas where detailed mapping had been done, the following six stratigraphic sections were studied: (1) Hidalgo-Laguna de Leche; (2) Laredo-Cameron Railroad; (3) Laredo-Monterrey highway; (4) San Ignacio-El Sauz; (5) Roma-Mier-Gral. Trevino; and (6) Rancherias-San Pedro de Roma composite Fayette section.

These sections afford an excellent opportunity for comparative study. Except for the fourth and sixth sections, all are traversed by highways or roads and in most cases reveal the formations to very good advantage. Thicknesses were estimated by automobile traverse and Brunton dips across the first three of these sections, but the latter three were mapped and measured by plane-table survey.

The studies of several well known micropaleontologists in the laboratories of the Humble Oil and Refining Company have substantially corroborated most of the contacts as they are given in this work. Hundreds of surface samples have been collected and these, together with cuttings from wells drilled throughout the area, have provided numerous determinations supporting the designated contacts as the writers have traced them on the ground.

CRETACEOUS-EOCENE CONTACT

The Cretaceous-Eocene contact crosses the Rio Grande from Texas into Mexico 1 mile downstream from the Blesse Ranch, or approximately 3 miles upstream from the Webb-Maverick County line. This contact, as described in detail by L. W. Stephenson,[10] shows the basal Midway beds of the Eocene to be underlain by Upper Cretaceous beds of Navarro age. While there is no apparent angular unconformity at this locality, the faunal contrast as well as the lithologic break make this one of the most interesting outcrops in the region. Typical assemblages of Upper Cretaceous Navarro and Eocene Midway fossils are found respectively below and above the contact. The Navarro fossils are found in greenish gray, glauconitic sandstone separated from the Midway by about 40 feet of greenish gray clay shales. The basal Midway is made up of several beds of

[9] L. W. Stephenson, "The Cretaceous-Eocene Contact in the Atlantic and Gulf Coastal Plain," *U.S. Geol. Survey Prof. Paper 90* (1914).

[10] L. W. Stephenson, *op. cit.*

fossiliferous gray limestone 1-2 feet thick, interbedded with greenish gray sandstone. Some mud-balls derived from the underlying Cretaceous clay are found locally in the very bottom of the limestone.

From the point where this contact crosses the Rio Grande into Mexico it can be followed southwest and south through the following three localities mentioned by C. L. Baker:[11] (1) a low bluff about 0.75 mile from the Rio Grande where the Arroyo Caballero enters the flood plain of the river; (2) the west bank of the Rio Grande flood plain 0.75 mile downstream from the mouth of the Arroyo Caballero; and (3) in the Arroyo del Amole about 6 miles upstream from the Trinidad ranch house. At each of these localities there is an erosional, as well as a faunal, unconformity.

From the Arroyo del Amole this contact extends almost due southward until it crosses the State line into Nuevo Leon, several miles southeast of the Laguna de Leche corner. From here it bears southeasterly along the northeast flank of the Salado arch and then swings around the southeasterly plunging axis of this structural feature. The outcrop of this contact, after it crosses the Rio Salado just above Tortillas, makes another southward swing along a prominent sandstone ridge in the Navarro, west of the Rio Sabinas in the La Lajilla area. Near Piedras Pintas it crosses the Rio Sabinas and on the south it is lost under a covering of gravels and caliche and is visible only intermittently down through the Agualeguas and Cerralvo areas to the Rio Pesqueria. As Tatum has indicated, south of Tortillas, a massive sandstone development is found near the basal Eocene contact. These red-weathering quartzitic sandstones are very prominent in the La Lajilla area and many excellent outcrops are found between Agualeguas and Gral. Trevino. Southward these sandstones are found in the vicinity of O'Campo east of Cerralvo where erosion has cut through the gravel and caliche. Still farther south these sandstones become fossiliferous. They crop out on the road from Cerralvo to Herreras and finally at the Cerro Colorado between Herreras and Ramones. Outliers of these same fossiliferous red-weathering quartzitic sandstones are found north and northwest of Ramones.

The three most notable changes in the Cretaceous-Eocene contact as it extends southward into Mexico are the following.

1. Although the typical Midway fossils are found at many places throughout the length of this outcrop, they are not found associated with the same ledge-forming limestone in the southern and central part of the area that characterizes their appearance in the Rio Grande sections.

[11] C. L. Baker, personal communication to A. C. Trowbridge, *U.S. Geol. Survey Bull. 837* (1932), pp. 30-33.

2. The massive red-weathering quartzitic sandstones which begin to appear near the basal Eocene contact below the Tortillas area are absent in the northern part of the area.

3. The basal Eocene beds are underlain by successively older Cretaceous beds at the contact as the contact is followed southward. Though there is Navarro beneath the Eocene Midway at the Rio Grande sections, the writers find the Midway resting on Papagallos, or Taylor, in the vicinity of Agualeguas, Cerralvo, and Ramones. It seems quite likely that even though an unconformity can not be seen clearly, all along the outcrop of this contact southward from Laguna de Leche, such a condition may indeed exist because of the apparent post-Cretaceous and early Eocene subsidence of the Rio Grande embayment area.

MIDWAY FORMATION

The Midway formation is the basal part of the Eocene in this province. It is well exposed along the Rio Grande for a distance of 5 miles downstream from the Blesse ranch house at the mouth of the Arroyo Caballero on the Mexican side of the river and crops out in a narrow belt 2–5 miles wide east of the Cretaceous-Tertiary contact, throughout the entire length of the area.

As already indicated, the Rio Grande section shows a series of prominent fossiliferous limestone ledges 10–12 feet thick at the base of the Midway. At a point about 1 mile down the river from the Eocene-Cretaceous contact these basal limestones dip beneath the bed of the river and they are overlain by several beds of massive soft gray glauconitic sandstone. In the top of this sand section numerous bright yellow-weathering nodular, calcareous concretions occur. From here upward appear the dark gray-to-black marine shales from which an almost complete Midway faunal assemblage may be collected. The following is a list of some of the fossils found at this locality.

Cucullaea texana Gardner
Ostrea crenulimarginata Gabb
Ostrea pulsaskensis Harris
Venericardia hesperia Gardner
Venericardia whitei Gardner
Venericardia alticostata Gardner
Venericardia smithii Aldrich
Natica sp.
Volutocorbis sp.
Terdo maverickensts Gardner
Enclimitoceras vaughani Gardner
Turritella humerosa Conrad

Small disc-shaped iron carbonate concretions 4–10 inches in diameter with dark purplish red colors are conspicuously scattered through these fossiliferous shales.

From this point down the river, the Midway is unconformably overlain by the basal sandstones and sandy shales of the Indio forma-

tion (Figs. 2, 3, and 4). The middle and upper parts of the Midway are characterized by many beds of hard platy argillaceous sandstone and numerous yellow-weathering calcareous concretions 1–3 feet in

FIG. 2.—Wilcox-Midway angular unconformity at bend of Rio Grande below Blesse ranch house.

FIG. 3.—Wilcox-Midway angular unconformity at bend of Rio Grande below Blesse ranch house.

diameter interbedded with the dark marine shales. Thinly bedded soft gray sandstones are here and there found in lenses; many of them are glauconitic and some are micaceous. The shales for the most part are non-calcareous and this fact is commonly the chief distinguish-

ing characteristic of the Midway from the underlying calcareous Papagallos shales of Taylor age in the Cretaceous.

The highest beds of the Midway exposed along the Rio Grande are dark gray and black marine shales found at the mouth of the Arroyo Loma Blanca, which enters the Rio Grande on the Mexican side of the river about 4 miles south of the point where the south line of Maverick County, Texas, intersects the river. While the Midway shale at this locality is overlain unconformably by the basal sandstones of the Indio formation, it does not appear as if the unconformity is nearly as angular as that seen in the outcrops of this contact farther up the river (Figs. 2, 3 and 4).

FIG. 4.—Thin-bedded shaly sandstone of Indio formation on Rio Grande just above Midway-Indio contact.

The thickness of the Midway increases rapidly toward the south. There is only 200 feet of Midway exposed on the Rio Grande at the Cretaceous contact, but on the road west from Hidalgo, this thickness has increased to 400 feet. From measured sections and information gained from core drilling on the San Ambrosio Ranch, it is estimated that the Midway is 513 feet thick at the point where the Laredo-Monterrey railroad crosses its outcrop, and 643 feet thick where it is crossed by the Laredo-to-Monterrey highway. In the section west of San Ignacio there is an estimated thickness of 650 feet, and the reports of micropaleontologists on well samples from the district west of Mier show 660 feet of Midway in that area. It should be noted that though these increasing thicknesses may be due to actual thickening of the Midway beds as deposited, they might also be considered as being related to a possible Indio-Midway unconformity.

The conditions of sedimentation are such that it is difficult to see the actual contact between these two formations under circumstances that would admit of a detailed examination of their relationship. Where this contact is exposed on the Rio Grande the unconformity is very angular. It is thought quite possible that similar conditions might persist toward the south.

The outcrop of the Midway is for the most part characterized by lowland topography. From the Rio Grande on the north to the San Juan on the south, it covers flats of relatively barren soil with much detrital material formed from the breaking down of the dark red iron-carbonate concretions.

Though the massive red-weathering quartzitic sandstones previously mentioned as characterizing the Cretaceous-Eocene contact south of Las Tortillas are considered to be of Midway age by Tatum and many others, some geologists in the area have suggested that these big sandstones that are so well developed near Agualeguas, Gral. Trevino, Cerralvo, and Ramones may be outliers of overlapping Wilcox. The writers do not have the detailed information necessary to clarify this point at this time and feel inclined to withhold their opinions until more work is done which shall establish these stratigraphic relations.

INDIO FORMATION

The Indio formation is the representative of Wilcox deposition in this province. As exposed along the Rio Grande it is unconformable with the Midway below and the Carrizo above. Here, as in the Midway-Cretaceous contact, there is no evidence of this unconformity continuing southward, but a corresponding cumulative thickening of the section is noted. The outcrops of the Indio range in width from 3 miles in some of the steep-dipping areas east of Zancudo to 14 miles where it is exposed on the crest of the broad Aldamas anticline.

This formation is composed of thin beds of sandy shale that present a characteristic banded appearance on their outcrop (Fig. 4). Massive cross-bedded micaceous sandstones are found alternating with thick beds of plastic red and gray clays. Platy argillaceous ripple-marked sandstones are common throughout the whole Indio section, as are the large biscuit-shaped calcareous concretions. A large amount of gypsum, some lignitic material, and several fossil horizons are noted.

The Indio formation is well exposed along the Rio Grande for a distance of 12 miles. From the point where it is first seen unconformably overlying the Midway shales 1 mile below White Bluff, outcrops

are persistent along both the Mexican and American banks of the river down as far as the mouth of the Arroyo del Amole on the Mexico side of the river. For the most part these outcrops are characterized by high banks of well banded shaly sandstones (Figs. 2 and 4) or great bluffs of massive yellow-weathering gray sandstone. These sands locally become indurated and hold up prominent strike ridges. The "Puerto Colorado" scarp at kilometer 1,188 on the Laredo-Monterrey highway is near the bottom of the Indio formation and is typical of the high massive sandstone ridges found all through the Indio section. Small disc-shaped iron-carbonate concretions of purple-red color are found in the shales, as are the larger yellow limestone concretions. Cone-in-cone structure is seen in many of the concretions and the peculiar septarian concretions of nodular shapes are also common. Hard platy, argillaceous sandstones are found through the shale sections and form one of the consistent features of the Indio outcrops throughout the area. An 8-inch ledge of hard brown slabby sandstone with *Ostrea thirsae* is seen over a wide area just above the lowest sandstone. Several other thin fossil beds containing small gastropods and bivalves were found on the west of the Aldamas anticline and a prominent bed of well preserved specimens of *Cornulina armigera* and *Cardium tuomeyi* extends along the east flank of this structure.

The thickness of the Indio formation in Maverick County, Texas, is given as 600–800 feet by Getzendaner.[12] According to Nielson[13] there is 1,188 feet of Indio at the Trinidad Ranch and 1,518 feet of it in the section west of Hidalgo, while the railroad section and the highway section show 1,919 and 1,985 feet respectively. In the San Ignacio-Sauz section 2,930 feet of Indio was measured and 3,240 feet of beds has been assigned to the Indio in the Mier-Aldamas region, on the basis of micropaleontology.

Indio topography here is much like that seen near the Rio Grande in the northwest corner of Webb County, Texas, with its series of high ridges of characteristically red-brown-weathering massive gray and brown sandstones and rather deeply cut valleys between. Many of the Indio ridges, notably the Puerto Colorado scarp, may be traced from one end of the sector to the other.

CARRIZO SANDSTONE

The Carrizo sandstone is considered the basal part of the Claiborne group in this paper. Its outcrop covers a belt 1–4 miles wide

[12] F. M. Getzendaner, *Mineral Resources of Texas* (December, 1931).

[13] H. Nielson, personal communication.

extending through the entire area. Because of its characteristic red-weathered appearance it is perhaps the easiest formation in the Eocene to recognize. Where it is first seen in the Rio Grande section, it exhibits angular unconformity with respect to the underlying Indio formation. Though the writers have not found good exposures of this contact on the Mexican side of the river, the outcrops of these beds along the San Ambrosio drainage about 3 miles north of the Rio Grande on the American side show this unconformity very clearly.

The Carrizo is especially notable in this area for its massive soft white sandstones associated with rather hard ferruginous layers. The resultant castellated erosion forms are characteristic of the Carrizo outcrops throughout this region. High banks of the massive Carrizo sandstone may be seen on the banks of the Rio Grande on the Mexican side under the Canovillas Ranch 25.5 miles north of Hidalgo on the river road and in the deeply cut arroyos between this ranch house and the Trinidad gate 1.5 miles north of it.

While the Carrizo sandstone is essentially a sandy formation throughout, it has numerous beds of clay and shale. Thin layers of ferruginous sandstones and hematites, argillaceous platy sandstones and calcareous concretions are also found interbedded with the massive white sandstones. Cross-bedding is very common in almost all of the sandstones and a mottled yellow and gray pattern is commonly seen on the weathered outcrops. Mica, as a constituent of the sandstone, is found in abundance through most of the Carrizo section in Mexico in contrast to its almost complete absence in the same beds of the Texas section.

The thickness of the Carrizo sandstone in the Rio Grande region is given as ranging from 100 to 400 feet, by various writers. This interval on the road west from Hidalgo has increased to 1,122 feet, then to 1,179 feet in the section across the railroad, and to 1,176 feet at the highway to Monterrey. Only 947 feet of Carrizo was measured in the San Ignacio-Sauz section and the Mier-Cerralvo area showed only 810 feet. The thickening of this formation is most notable from the Rio Grande to the Laguna de Leche section. It maintains a fairly constant thickness across the area from the railroad section to the highway section, but then becomes gradually thinner toward the south.

The most noteworthy feature of the outcrop of the Carrizo sandstone is its widening over the crest of the Guerrero dome. The high erosion-resisting dip-slope scarps that are formed by the sandstones of this formation can be traced from the Rio Grande to the Rio San Juan in the south. These sandstones are exceptionally well exhibited

at the "Once Lomas," a series of dip-slope hills making a scarp around the south end of the Aldamas anticline.

MOUNT SELMAN FORMATION

In this paper the Mount Selman formation is considered to include the Bigford formation of Trowbridge as its basal member. The Mount Selman is found cropping out along the Rio Grande for a distance of nearly 40 miles. The width of the outcrop varies from about 2 miles at San Ignacio to almost 20 miles northwest of Nuevo Laredo.

The Bigford member of the Mount Selman is easily distinguished by the large amount of brightly colored material in its weathered outcrop. Brown ferruginous sandstones are interbedded with gray, green, pink, and purple clays. Small bands of ironstone concretionary material, much gypsum and sulphur, and numerous beds of carbonaceous shale all contribute to the distinctive aspect of this part of the section. Interbedded with these clays and shales are numerous beds of soft thin-bedded-to-massive white, gray, and brown sandstones.

The Bigford member of the Mount Selman overlies the Carrizo sandstone with apparent conformity and is first seen along the Rio Grande about 3 miles below the Canovillas Ranch. Good exposures of the sandstones of the lower Mount Selman are seen in the Arroyo de las Iglesias about 5 miles below the Canovillas Ranch on the river road, and in the deep Arroyo Agua Verde 4 miles north of Hidalgo on the same road. The uppermost sandstone of the Bigford member of the Mount Selman formation is exposed in the bed of the Rio Grande at Hidalgo, Coahuila.

The upper Mount Selman has the massive Palafox sandstone as its basal member. The Rio Grande outcrop of this prominent ridge-forming sandstone can best be seen on the American side, where it forms a high cliff extending down the east bank of the river from the mouth of Espada Creek to the bluffs east of Palafox. Farther down the river and farther up in the section, is a thin clay-shale section, and then another massive sandstone horizon which crosses the river near the town of Columbia, Nuevo Leon. Above these massive sandstones is a clay-shale section that includes near its base the cannel coal horizons still worked on the American side of the river at Santo Tomas,[14] and formerly worked on the Mexican side of the river near Columbia.

According to Lonsdale's measurements there is 1,835 feet of Mount

[14] G. H. Ashley, "The Santo Tomas Cannel Coal, Webb County, Texas," *U.S. Geol. Survey Bull. 691-i* (1919).

T. W. Vaughan, "Reconnaissance in the Rio Grande Coal Fields of Texas," *ibid.*, *Bull. 164* (1900).

Selman in Webb County, Texas. This interval has increased to 1,928 feet in the Monterrey highway section. The measured section at San Ignacio showed 2,587 feet and the Mier-Gral. Trevino section showed 3,316 feet.

Excellent assemblages of a typical Weches fauna are found at the top of the Mount Selman in cuttings from the La Presa well of the Ohio-Mexico Oil Corporation about 10 miles south of Mier. Some megascopic fossils were found in the San Ignacio-Sauz section.

What appears to be a promising horizon for the production of oil and gas was discovered 265 feet below the top of the Mount Selman when the aforementioned La Presa well encountered commercial gas at depths of 1,305 and 1,480 feet. Subsequent developments on both sides of the Rio Grande have shown this horizon to be gas-producing in five widely scattered localities. These producing sandstones are believed to be correlated with the Queen City sandstones of Texas.

For the most part, Mount Selman outcrops are characterized by valley topography because of the predominance of shales in the section, but some of the highest ridges in the area are those held up by the massive sandstones of the middle and lower part of this formation. The Mount Selman formation appears to have better developed sandstone members in the Mexican section than we normally find in the Texas section. The Palafox sandstone, like the Puerto Colorado sandstone of the Indio and the "Once Lomas" sandstone of the Carrizo, may be traced from the Rio Grande all the way down to the Rio San Juan.

COOK MOUNTAIN FORMATION

The outcrop of the Cook Mountain formation ranges from a little more than 2 miles wide east of Las Aldamas to 8 miles wide across the La Presa structural area.

The bottom of the Cook Mountain is found in conformable contact with the red and gray gypsiferous shales at the top of the Mount Selman formation in the Rio Grande near Las Comitas Ranch on the Mexican side of the river about 10 miles upstream from Laredo. This same contact recrosses the Rio Grande at San Ignacio and after leaving a small lobe of Mount Selman exposed in the bend of the river south of San Ignacio on the American side, the contact goes back into Mexico. It extends thence southward near the river through the Ramireno Ranch and crosses to the American side in a second place. After leaving another small lobe of Mount Selman exposed in another bend of the river, this contact again crosses into Mexico. It comes up

to the bed of the river also at the Zapata-Guerrero bridge and finally crosses again into Mexico.

The top of the Cook Mountain crosses the Rio Grande into Mexico just below the small Isle of Chapeno, several miles south of Falcon, Starr County, Texas. It holds up a yellow-weathering scarp extending southward from along the east side of the Arroyo Saucito to a point on the west edge of Ciudad Mier. It continues southward, makes a broad S-turn around the south end of the La Presa anticline, and continues southward again, crossing the Rio San Juan near Tecomate.

It is seen from the foregoing descriptions that the bottom of the Cook Mountain formation as it is drawn in this work is approximately at the same horizon as the top of the Cook Mountain formation as drawn by Tatum and that therefore all of the beds designated as Yegua by Tatum are found within the limits of the Cook Mountain formation of this paper.

Since the position of the Cook Mountain-Yegua contact Mexico has been a major point of controversy for several years, this horizon was traced down the river on the American side of the river from the point where Trowbridge places it 7.5 miles east of the Laredo Post Office to the aforementioned locality near the Chapeno Ranch on the Rio Grande. In this connection it should be noted that this Cook Mountain-Yegua contact of Trowbridge near Laredo has been checked by Lonsdale and its identity has not been questioned by any geologists in the area who have actually traced the beds southward from La Salle County, where they were designated by Alexander Deussen in his original paper.

The Cook Mountain formation is exposed along the Rio Grande for a distance of more than 90 miles. Good outcrops of its characteristic brightly colored sandstones and shales are found at numerous places throughout the region. The typical Cook Mountain fauna may be found from the Laredo district all the way down the river to the place where the top of the Cook Mountain crosses into Mexico at Chapeno and from here southward over the whole area covered by Cook Mountain beds as far as the Rio San Juan.

The Cook Mountain is composed of a series of thick massive, glauconitic sandstones mostly greenish gray-brown in color. Large brown limestone concretions are found in many of these sandstones. Many of these concretions are fossiliferous on their outer edges and are very hard. There are many fossil beds throughout the Cook Mountain section. It is indeed the most fossiliferous part of the entire Eocene section. The following is a list of some of the fossils

recognized in the outcrops of the Cook Mountain formation of this area.

Natica dumblei Heilprin	*Ostrea georgiana* Conrad
Cerithium texanum Heilprin	*Callocardia astartoides* Gardner
Lacinia alveata Conrad	*Turritella* sp.
Venericardia planicosta (Lamarck)	*Pteropsis lapidosa* Conrad
Ostrea alabamiensis Conrad	*Corbula deusseni* Gardner
Volutocorbis petrosa Conrad	*Cornulina armigera* Conrad

According to Trowbridge, the thickness of the Cook Mountain in Webb County is about 700 feet. These beds have increased in thickness at San Ignacio to 1,350 feet, and in the region south and west of Mier there is 1,490 feet of Cook Mountain beds.

The outcrop of the Cook Moutain is characterized by a series of high ridges held up by the resistant sandstones with intervening strike valleys cut through the clay shale breaks in the section. The bright orange-yellow-weathering clays, the red and brown ferruginous sandstones, iron detritus, and red-weathering glauconitic sandstones contribute to make the outcrop of this formation one of the brightest color in the whole Eocene section and one of the easiest to identify.

YEGUA FORMATION

This formation, which was called "Cockfield" in the last publication of Trowbridge in the Rio Grande area, is here given the old name of Yegua, which was used by the same writer in his earlier paper. Since the top of the Yegua as drawn by Tatum is considered by the present writers to be approximately the bottom of this formation, most of the beds considered by Tatum as being Fayette will be found within the limits of the Yegua formation of this paper.

The Yegua formation is the uppermost member of the Claiborne group. Though its outcrop is only about 3 miles wide at Mier and 5 miles wide on the Rio San Juan, it is almost 8 miles across in the area covered by the Ochoa structure.

The Yegua formation consists of a series of dark greenish gray, pink and purple clays, and brown carbonaceous shales with several prominent soft gray-to-buff massive sandstones. The Yegua has a fairly plenteous representation of Claiborne fossils, but it is not as complete as in the Cook Mountain beds. Perhaps the most prominent faunal feature of the Yegua in this area is that it marks the bottom of a series of heavy oyster beds which extend from the bottom of this formation far up into the Jackson. Although some *Ostrea georgiana* are found in the Cook Mountain beds of this area, the thick beds formed by reefs of these shells are not found below the bottom of the Yegua. In the upper part of the Yegua south of the Rio Grande a

bed of silicified volcanic ash is found. Associated with it are oyster fragments and small specimens of *Natica dumblei*. This ash bed does not seem to be recognizable as the strike of the beds is followed northward into the United States.

The bottom of the Yegua is characterized by a series of gray and red clay-shales with a very heavy oyster bed (*Ostrea georgiana*) beneath a prominent bench-forming massive soft gray sandstone. This basal sandstone member of the Yegua is referred to in this report as the Mier sandstone and a typical exposure of it may be seen in the town of Ciudad Mier, Tamaulipas. Immediately above the Mier sandstone sequence is a similar series of beds with an almost identical sequence of gray and red clay-shales overlain by a heavy bed of oysters and this in turn overlain by another massive ridge-forming sandstone. This upper sandstone member is referred to in this work as the Alamo sandstone and a typical exposure of it may be seen along the east bank of the Rio Alamo downstream from Ciudad Mier. Both of these beds with their exceptionally similar sequences have been traced more than 50 miles in Mexico and brought up to the Rio Grande for correlation with the Texas section on the American side. The lower of these two series, or the Mier sandstone, and oyster beds which are considered to be the basal part of the Yegua cross the Rio Grande into the United States a short distance east of the mouth of the Arroyo de Saucito on the Mexican side. Both the Mier sandstone and its underlying oyster beds and the Alamo sandstone and its underlying oyster beds have been traced on the ground by the writers as far as the Arroyo Tigre in Zapata County, Texas. From this point northward to Laredo the contact of the Cook Mountain-Yegua was traced by airplane reconnaissance to the locality 7.5 miles east of the Laredo Post Office where Trowbridge places the bottom of his Cockfield formation. At this point there is an oyster bed having under it a sequence of beds similar to that found under the Mier oyster beds in Mexico and along the Rio Grande.

The oyster bed east of Laredo moreover has been traced southward by F. C. Owens[15] of the Humble Oil and Refining Company, as far as Chapata Creek 7.5 miles northeast of San Ignacio, Zapata County, Texas. Farther south it can not be traced on the ground bebecause of the mantle of windblown sand that covers the area. The sequence of beds immediately below it, however, may be easily followed by airplane reconnaissance southward as far as the Zapata-to-Aguilares road in Zapata County. Along this road the same basal Yegua oyster bed and another higher oyster bed, the Loma Blanca

[15] F. C. Owens, personal communication, April, 1934.

oyster horizon of Owens, may be recognized. He has traced these two beds from this road southward to the Rio Grande where they are found to be the same as the Mier and Alamo oyster beds respectively.

It should be noted that although Trowbridge failed to find any fossils other than oysters and *Venericardia* in the beds he called Cockfield, Owens has found *Pteropsis lapidosa, Turritella nasuta, Natica dumblei,* and casts of other bivalves under his Loma Blanca sandstone as far north as central Zapata County; and *Modiolus texanus* has been found under Owens' lower sandstone which is correlated with the writers' Mier sandstone. The writers have made similar fossil collections from beneath both of these sandstones on both the American and Mexican sides of the river.

It is true that, as Trowbridge has been told, the Yegua beds in Mexico are fossiliferous, but it also seems to be true that this faunal facies extends farther northward along the strike into Texas than he thought. While some geologists are inclined to consider all of these highly fossiliferous beds as still belonging to the Cook Mountain, Miss Ellisor, of the Humble Oil and Refining Company's laboratory, is inclined to think that the megasopic paleontologic evidence should not be taken as a criterion for classification in this case because many of the forms previously considered to be typically Cook Mountain are being found all the way up through the Yegua and in some places even far up into the Jackson.

As already stated, the top of the Yegua formation is placed at the base of the big massive sandstone cropping out on the American side of the river at Salineno in Starr County. From this point the contact bears almost due south until the big bend of the river is reached just west of Los Guerras. Here it crosses into Mexico and runs southeasterly along the northeast flank of the La Presa anticline and later makes an abrupt swing toward the east around the north end of the Ochoa-Pescada anticline. It continues south along the east flank of the Pescada structure, crosses the Rio San Juan and swings completely around the south end of this fold. It recrosses the Rio San Juan toward the north and is found in a big synclinal development west of the south prolongation of the La Presa anticlinal axis. It finally crosses the Rio San Juan in a third place just west of the town of La Lajilla.

The Yegua formation has been measured in several places in the district south of Mier and is considered to be 1,543 feet thick. The same micro-fauna are found in these beds as are recognized in many of the Texas sections of the border province.

Except for the localities covered by the three or four prominent

sandstone members, the Yegua is characterized mainly by valley topography.

FAYETTE FORMATION

The Fayette formation is the representative of Jackson deposition in this province. It includes all of the beds designated as Fayette by Trowbridge in his latest report and also several hundred feet of clays and sandstones beneath the Roma sandstone member which he referred to the Cockfield. It represents all of the beds considered to be Frio by Tatum.

The bottom of the Fayette is found cropping out in the Rio Grande at Los Guerras, a small Mexican town 4 miles upstream from the Roma-San Pedro International bridge. At this locality the massive basal sandstone is found underlain by the variegated clays, carbonaceous shales, and lignite at the top of the Yegua. This basal sandstone member of the Fayette has two ledges, the lower of which is characterized by a thin layer containing an abundance of *Venericardia*. Immediately above these sandstones several thick oyster beds are found in gray gypsiferous shales. Included in these shales are numerous chalcedony replaced casts of what appear to be *Mesalia claibornensis*. This fossil bed has been traced many miles in Mexico and into Texas and affords a very valuable datum for stratigraphic correlation.

The Fayette formation is composed mainly of sands and sandstones with interbedded sandy and calcareous pink, gray, red, and green shales. Beds of volcanic ash are common in the middle and upper part of the formation in this area. Silicified wood is plentiful and considerable chalcedony is present. Most of the sandstones are rather soft, coarse, and cross-bedded. The sandstones of the lower part of the Fayette formation are of considerable economic importance in the light of the discovery of commercial gas in large quantities at the Rancherias well No. 1 of the Ohio-Mexico Oil Corporation. According to paleontologic determinations, these beds are the equivalent of some of the producing horizons of the Pettus field in Bee County, Texas.

The Fayette is very fossiliferous throughout its entire thickness and, like the Yegua, it is characterized by the presence of numerous heavy oyster beds (*Ostrea georgiana*). Many of the zonal determinations of *Foraminifera* made in the border province of Texas seem to be applicable here with considerable success.

The width of its outcrop in this small area is about 15 miles, but it is found this width because of the presence of the Palo Blanco syncline and the Rancherias anticline which lie just west of the Rio San Juan at Camargo.

The measured thickness of the Fayette beds in this area is 1,417 feet. This figure probably does not represent the total thickness of the Fayette, as there appear to be other Jackson beds east of the Rio San Juan at Camargo that are not included in this section.

STRATIGRAPHIC SECTIONS

1. *Hidalgo-Laguna de Leche section.*—Although this section is primarily intended to show the thicknesses and nature of the formations westward from Hidalgo, the road log begins at Nuevo Laredo, Tamaulipas. The thicknesses of this section were estimated by automobile traverse and Brunton dip measurements.

Since the Bigford beds of the Mount Selman formation are the youngest sediments exposed in Mexico across the Hidalgo section, the writers use the figures of J. T. Lonsdale of 1,165 feet of upper Mount Selman and 675 feet of Cook Mountain to augment the columnar section in this area.

Special notice should be taken of the fine exposures of the massive ridge-forming sandstone of the upper Mount Selman that are seen at Palafox on the American side of the Rio Grande across from Hidalgo. This prominent sandstone ridge crosses the Nuevo Laredo-to-Hidalgo road at 29.9 miles, or about 4 miles south of Hidalgo. This horizon is referred to in these sections as the Palafox sandstone member of the upper Mount Selman. While it is not considered as a formation contact in this work, it is nevertheless a significant horizon in stratigraphic studies, since it has been traced as a ridge-forming sandstone as far south as the Rio San Juan. It was considered by Trowbridge as being near the base of his Mount Selman formation as differentiated from the underlying Bigford. Since the writers are here considering the Bigford beds as the lower part of the Mount Selman, they regard this bed as the base of the upper part of the Mount Selman.

The cannel coal beds that are mentioned in the following road log at 23.9 miles should also be given special note because of the fact that this is the only place where commercial coal appears in any of the sections studied in this work. A complete description of this coal-bearing horizon may be found in the publications of the United States Geological Survey and the Bureau of Economic Geology of the University of Texas.[16]

By setting the speedometer at 00.0 at the city water tank in the Obregon Park at Nuevo Laredo and heading northward toward

[16] G. H. Ashley, *op. cit.*
T. W. Vaughan, *op. cit.*

Hidalgo, Coahuila, the following automobile log of the road may be obtained in miles, showing notes on the contacts and stratigraphy of the beds crossed.

Miles	
00.0	City water tank in Nuevo Laredo (Cook Mountain)
4.5	Cook Mountain-Mount Selman contact, red and gray clay-shales overlain by soft yellow and gray coarse sandstone
5.0	Gate
6.3	Gate
12.8	Longoria ranch house at right, or east, of road
13.8	Gate road to Los Torres Ranch, at left or west
20.0	State Line monument Nuevo Leon, Tamaulipas
21.8	Arroyo, soft shaly beds
22.8	Columbia, Nuevo Leon, Plaza
23.0	Garita—Customs Inspection
23.9	Abandoned coal mines (cannel coal in Mount Selman formation)
27.8	Gate, Tepeyac ranch house
28.5	Castellated sandstone east of road in Mount Selman
29.9	Palafox sandstone, massive sandstone at base of upper Mount Selman
34.0	Plaza in town of Hidalgo, Coahuila. Good outcrops of massive gray sandstone at top of Bigford member of Mount Selman formation cropping out in Rio Grande
37.4	Ferruginous sandstones in variegated clay shales
38.1	Typical Bigford beds of lower Mount Selman, variegated shales
38.5	Encino Ranch
38.7	Encino tank. Top of Carrizo sandstone traced to here from Rio Grande
39.3	Road comes in from left
40.2	Gate at Carrizo sandstone. Massive red-weathering sandstone
43.0	Desedero Ranch
43.7	Gate at corner of three fences, S. 70W., N. 67E., and N. 10W.
45.7	Fence corner at green glauconitic sandstone, weathering red
47.2	Take left fork
49.6	Gate
49.7	Take left fork
50.5	Top of massive gray sandstone ridge in Indio formation
50.9	Road comes in from left
51.1	Gray-green glauconitic Indio sandstone, weathers red
51.2	Indio massive sandstone in arroyo. Good water hole
52.7	Bottom of Indio massive sandstone scarp. Top of Midway at base
53.5	Take cross road going north along west face of bottom of Indio scarp over black shale and yellow calcareous concretion
54.7	Meet old road along straight cut-out line. Turn left and west
55.6	Midway fossils cropping out along road
56.1	Eocene-Cretaceous contact

From here this road continues westward over five successive scarps of Upper Cretaceous fossiliferous sandstones, reaching the La Puerta Ranch at about 60 miles from Laredo and the Laguna de Leche at 64 miles from Laredo.

The thicknesses given herewith for this section are from Nielson's[17] measurements of the Indio, Carrizo, and Bigford beds west of Hidalgo and from Lonsdale's[18] estimate of the upper Mount Selman in the Rio Grande region of Webb County, Texas.

[17] H. Nielson, personal communication.

[18] J. T. Lonsdale and James P. Day, "Ground Water Resources of Webb County, Texas," *U.S. Dept. Int. Memo. for Press* (February 9, 1933).

		Feet
Mt. Selman	Upper Mount Selman	1,165
	Bigford member	759
Carrizo		1,122
Indio		1,518
Midway		400

1. *Laredo sections.*—Although both the railroad and the highway from Laredo to Monterrey cut across the Cook Mountain and Mount Selman beds at an angle oblique to their strike, in many places they are nearly at right angles to the strike of the beds from the Palafox sandstone downward in the section. On account of the relatively small amount of dip, the Cook Mountain and the Mount Selman formations do not appear on their outcrops on either of these two roads to as good advantage as the lower beds. It was therefore necessary to measure a section for these upper formations away from the roads to complete the sections for the Laredo area. The thicknesses given for beds below the Palafox sandstone were estimated from automobile and Brunton traverses.

2. *Laredo-Monterrey railroad section.*—This section may be seen from a road along the north side of the railroad grade. The following road log shows miles from Nuevo Laredo as well as railroad kilometer posts where these come in close proximity to localities mentioned.

Miles	*RR–Kl.*	
0.0		Main Plaza Nuevo Laredo (Cook Mountain)
0.6		Railroad crossing
0.9		City water tank and park
1.8		Military Cuartel
2.3	1288	Railroad to Monterrey and highway parallel from this point
2.9	1287	Railroad section house
4.0	1285	Arroyo
4.3	1284.5	Top of ridge
6.2	1281	Arroyo
6.5		Arroyo Coyote crossing (red clay)
9.0	1277	Arroyo
9.4	1276	Sanchez Nuevo (section house)
9.9	1276	Cook Mountain-Mount Selman contact (red clay north of road)
11.0		Arroyo
11.3	1273.6	Sanchez railroad siding
14.6	1268	Top of ridge (Mount Selman)
15.8	1266	Top of ridge (Mount Selman)
16.7		Arroyo
17.2	1265	Sandstone ridge (Columbia sandstone, Mount Selman)
17.7	1264	Palafox sandstone (Juanita ranch house north of road—Mount Selman)
17.9	1263	Tamaulipas-Nuevo Leon boundary line
19.1	1262	Santa Clara, sandstone beds (field north of road)
19.3		Old railroad grade to Columbia
19.5		Garita (Custom outpost)
20.0	1260.7	Jarita railroad station
20.4		Top of gray sandstone ridge
20.5	1259	Fields on both sides of road
23.5	1255	Top of sandstone ridge (Carrizo)
24.1	1254	Bottom of sandstone (field north of road)
25.1	1253	Top of sandstone ridge (Carrizo)

26.1	1252	Top of sandstone ridge (Mathews Ranch, 0.25 mile north of road)
26.4		Field south of road
26.8	1250	Altos station (field north of road)
29.2	1247	Brown calcareous sandstone (Indio)
29.9	1245	Puerto Colorado sandstone (base of Indio)
30.2		Yellow calcareous concretions (top of Midway)
30.6	1244	Huisachito siding
31.2	1243	Midway-Cretaceous contact (approx.)
35.2	1237	Cameron well (Midway-Cretaceous contact 3.5 miles N. 10 E. from well)
38.2	1232.5	Cameron railroad station

The following thicknesses have been assigned to the Eocene formations encountered in crossing this section.

		Feet
Cook Mountain		
Mount Selman	Upper Mount Selman	1,124
	Bigford member	804
Carrizo		1,179
Indio		1,919
Midway		513

3. *Laredo-Monterrey highway section.*—This section may be seen along the paved highway from Laredo to Monterrey. The following road log shows miles from Nuevo Laredo as well as highway kilometer posts (distances from Mexico City) where these are in close proximity to localities mentioned.

Miles	*Kl.-Posts*	
0.0	1230	Main Plaza at Nuevo Laredo (Cook Mountain)
0.4	1229	Railroad crossing
2.8	1225	Flying field north of road
4.2	1223	Arroyo Coyote bridge
6.6	1219	Top of orange-red sandstone ridge (Cook Mountain)
9.7	1214	Top of ridge (Radio station)
13.9	1208	San Antonio Garita (Custom outpost)
14.9	1206	Top of ridge (lower Cook Mountain)
16.1	1204	Top of low bridge
17.0	1203	Cook Mountain-Mount Selman contact (red clay found north and south of road)
20.1	1198	Top of ridge
22.0	1195	Columbia sandstone ridge
22.7	1194	Palafox sandstone
23.8	1192	Carrizo sandstone ridge
24.4	1191	Piedras Pintas Ranch
25.1	1190	Carrizo sandstone ridge
26.8	1188	Puerto Colorado (sandstone base of Indio)
26.9	1187	Yellow calcareous concretions in top of Midway
28.8	1184	Tamaulipas-Nuevo Leon boundary line

The following thicknesses have been assigned to the Eocene formations encountered in crossing this section.

		Feet
Cook Mountain		
Mount Selman	Upper Mount Selman	1,124
	Bigford member	804
Carrizo		1,176
Indio		1,985
Midway		643

4. *San Ignacio-Sauz section.*—The following section was measured in the vicinity of San Ignacio, Tamaulipas, 35 miles south of Laredo, Texas. The section was measured by plane-table method and the beds described from surface exposures and numerous hand-auger samples. Only approximately half of the Cook Mountain formation is exposed on the Mexican side of the Rio Grande at San Ignacio. The total thickness of the formation is approximately 1,350 feet. The thickness of the Midway is estimated.

Description	Thickness Feet
Yellowish gray medium-grain sandstone (Cook Mountain)	10
Red selenitic sandy clay	22
Brown and greenish gray glauconitic sandstone, weathers red	139
Gray glauconitic fossiliferous sandstone	1
Red and gray selenitic shale	73
Soft medium-grain glauconitic green sand	42
Glauconitic green sand containing many medium-size oysters	4
Covered by mantle of windblown sand (predominately sand section)	302
Green selenitic clay	10
Gray fine-grain glauconitic fossiliferous sandstone	42
Gray and brown clay (bottom of Cook Mountain)	8
Total thickness of Cook Mountain beds here exposed	653
. . . .	
Red and green shale and gray medium-grain sandstone (poorly exposed) (top of upper Mount Selman)	297
Brown massive-bedded fine-grain sandstone and red and green clay with limonite boulders	82
Brown argillaceous medium-grain sandstone and gray sandstone with small clay-ball inclusions	22
Brown selenitic shale and gray medium-grain sandstone	273
Gray and brown medium-grain sandstone with small clay-ball inclusions	29
Brown selenitic shale	54
Gray and brown massive cross-bedded medium-grain sandstone with small clay-ball inclusions	20
Brown selenitic shale contains small limonite concretions alternating with beds of gray sandstone having small clay-ball inclusions	138
Red and green plastic clay alternating with beds of gray friable sandstone containing small clay-balls	142
Gray medium-grain poorly consolidated sandstone with small white clay-ball inclusions	55
Brown selenitic shale and gray sandstone	86
Reddish brown medium-grain sandstone, poorly consolidated, and gray selenitic sandy shale	80
Brown sandy shale alternating with gray thin-bedded hard sandstone and soft yellow sandstone	42
Red and yellow medium-grain sandstone	97
Brown and gray clays with interbedded thin sandstones (two seams of cannel coal are exposed in Porcion 67 in these beds)	214
Brown and gray selenitic clay alternating with thin beds of yellow and brown sandstone	119
Gray medium-grain thin-bedded sandstone, weathers yellow and reddish brown	33
Gray thin-bedded sandstone and brown shale with siderite concretions	52
Light gray and yellowish brown poorly cemented sandstone characteristically mottled on weathering (Palafox sandstone member)	150
Gray and yellowish brown medium-grain sandstone	100
Dark gray medium-grain sandstone containing brackish sulphurous water. Outcrop in bed of Arroyo Salado	20

Description	*Thickness Feet*
Light gray coarse-grain sandstone, weathers in brown and yellow streaks, massive-to-irregular-bedded	126
White and brown coarse-grain sandstone weathering rusty yellow with white spots	66
Yellowish brown-to-brick red fine-grain sandstone	140
Thin-bedded yellowish brown sandstone and brown selenitic sandy shale with large yellow limonite concretions	89
Brown sandy shale	27
Brown sandy selenitic and glauconitic shale with foraminifers at base of Mount Selman	34
Total thickness of Mount Selman exposed in this section	2,587
. . . .	
Yellowish brown fine-grain coarse-bedded sandstone (top of Carrizo)	10
Coarse-grain brick red micaceous sandstone	41
Thin-bedded gray medium-grained sandstone, weathers brown	156
Gray medium-to-fine-grain sandstone, weathers brown	128
Gray and brown medium-grain sandstone	274
Gray medium-grained sandstone, weathers brick-red and forms prominent escarpment	249
Red and gray medium-to-coarse-grain micaceous sandstone	89
Total thickness of Carrizo sandstone exposed in this section	947
. . . .	
Gray sandy selenitic shale with a few thin streaks of brown sandstone (top of Indio formation of Wilcox)	94
Brown selenitic sandy shale with beds of yellow concretionary fossiliferous limestone and gray fine-textured sandstone	140
Brown ferruginous fossiliferous limestone	2
Gray sandy shale and fine-grain sandstone	108
Gray selenitic sandy clay and brown fine-grain sandstone, fossiliferous bed near base	222
Gray selenitic clay with limonite boulders alternating with thin beds of gray fine-grain sandstone	456
Fossiliferous sandstone, *Venericardia*, fragmental oyster casts and fucoids?	1
1–6-foot beds of gray and brown fine-textured sandstone interbedded with gray sandy shale containing limonite boulders 1–5 feet in diameter	138
Gray sandy shale with beds of limonite concretions and thin-bedded reddish-brown sandstone	130
Fossiliferous sandstone containing *Venericardia*, *Turritella*, and small oysters	1
Gray sandy shale with a few 2–4-foot beds of medium-grain silver-gray sandstone and beds of yellow concretionary limestone ranging from 4 inches to 1 foot in thickness	130
Fossiliferous gray sandstone	1
Gray and brown sandy shale alternating with thin beds of gray medium-grain sandstone	45
Brown sandy shale with large yellow limonite concretions	67
Fine-grain slightly argillaceous gray sandstone with a few thin beds of brown sandy shale containing limonite concretions	138
Gray sandy shale containing small limonite concretions alternating with thin beds of gray medium-grain sandstone	122
Fossiliferous sandstone, small oysters, *Venericardia*, and fucoids	1
Thin beds of gray sandstone alternating with heavy beds of brown and gray shale containing small limonite concretions	63
Gray and brown sandy shale	22
Gray thin-bedded sandstone and sandy shale	80
Yellow concretionary limestone	2
Gray sandstone	42
Gray medium-grained sandstone with thin beds of gray sandy shale	48
Silver-gray medium-grain thin-bedded sandstone	86
Gray massive sandstone and brown shale (poorly exposed)	187

Description	*Thickness* *Feet*
Gray sandy shale and thin-bedded argillaceous sandstone	25
Dark gray sand selenitic with red ferruginous concretions	7
Brown selenitic shale alternating with thin beds of brown medium-grain sandstone	62
Gray and yellow medium-grain sandstone	9
Gray fine-grain sandstone and fossiliferous calcareous sandstone	51
Dark gray selenitic shale and thin-bedded gray sandstone	67
Gray medium-grain sandstone	3
Brown selenitic shale and thin-bedded gray sandstone	41
Silver-gray medium-grain micaceous sandstone	7
Brown sandy shale with small limonite concretions and yellowish brown fine-grain sandstone	40
Gray selenitic sandy shale with small limonite concretions	17
Gray selenitic sandy shale with small limonite concretions alternating with beds of brown argillaceous sandstone	90
Silver-gray medium-grained sandstone	77
Gray medium-grained sandstone and brown argillaceous shale	108
Total thickness of Indio exposed in this section	2,930
. . . .	
Dark gray shale with numerous limonite concretions and thin-bedded silty sandstone, estimated thickness of Midway	650

The following thicknesses have been assigned to the Eocene formations in the preceding measured section described.

	Feet
Cook Mountain	1,350
Mount Selman	2,587
Carrizo	947
Indio	2,930
Midway	650

5. *San Pedro-Mier-Gral. Trevino section.*—The following section was made from a composite study of measured sections and well logs. Mileage is given for convenience in locating the interesting members of the section along the road. It should be noted that because of a lack of competent field evidence the Indio-Midway contact is not definitely fixed. The division of the 3,900 feet of combined thickness of these two formations here given is made on the basis of the consensus of opinion of several micropaleontologists who have studied the samples from the Aldamas well of the Ohio-Mexico Oil Corporation.

Miles		*Thickness* *Feet*
0.0	San Pedro de Roma on Mexican side of Rio Grande from Roma, Texas. Roma sandstone member of lower part of Fayette is exposed at International Bridge. Follow gas line of United Gas out as far as Los Guerras	
3.5	Los Guerras sandstone member at base of Fayette (Jackson), same as Salineno sandstone on United States side of Rio Grande. Purple and gray shale, lignite, and carbonaceous shale (top of Yegua)	20
	Bright-colored orange-stained clays with much gypsum	15
	Beds covered with alluvium, probably sandy shales	130
	Thin platy sandstone and sandy shale	10
	Light-gray and pink clays with oysters	25

Miles		Thickness Feet
5.8	Oyster bed	4
	Soft gray sandstone, brown concretions at base	19
	Yellow-brown sandstone	59
	Fossil bed	1
	Soft yellow sandstone and clay with gypsum	32
	Red clay	12
	Soft gray and yellow sandstone, sandy clay	159
	Silicified ash bed	2
	Gray sandstone	12
	Chalcedony fossils	1
6.8	Massive gray sandstone	40
	Gray sandstone, oyster sandstone and thin shale breaks	363
	Gray massive sandstone (Alberca sandstone)	80
7.0	Oyster bed in yellow clay (type locality Conrad, *Ostrea georgiana*)	25
	Thin sandstone, light gray and pink shale	107
8.4	Massive coarse-grained well bedded sandstone (Alamo sandstone)	100
	Yellow clay containing oysters	20
	Oyster sandstone	8
	Pink and gray clay with thin sandstone	58
8.7	Medium-soft, coarse-grained gray sandstone (Mier sandstone)	125
	Oyster sandstone	2
10.4	Yellow sandy clays, oysters, and red shale at base of Yegua	114
Total thickness of Yegua exposed in this section		1,543

. . . .

Miles		Thickness Feet
10.5	Medium-coarse-grained poorly bedded gray sandstone (Saucito sandstone, top member of Cook Mountain)	94
	Fossiliferous yellow-brown-weathering sandstone and shale	15
	Alternating sandy shale and sandstone, weathering brown	27
	Hard brown fossiliferous concretionary sandstone	3
	Bright yellow clay and sandstone, fossiliferous clay with gypsum	73
15.5	Lenticular glauconitic sandstone weathering to deep red	30
	Light yellow-to-gray gypsiferous shale	33
17.5	Hard dark brown sandstone and *Turritella* bed	1
	Soft yellow-weathering sandstone with fossils at base	19
	Yellow clay with adult form of *Ostrea georgiana*	12
	Loosely cemented gray sandstone	10
	Bright yellow-weathering clay	10
17.8	Conglomerate sandstone with black chert pebbles and fossils	10
	Cross-bedded gray sandstone	82
18.0	*Turritella* bed above blue-yellow clay	10
	Fossiliferous sandstone	8
	Gray sugary sandstone	54
	Soft sandstone and yellow-gray clay	46
18.4	Brown concretionary sandstone with fossils replaced by silica	7
	Sandstone and shale	37
	Shale containing purple disc-shaped concretions	45
	Soft gray sandstone	49
	Yellow-gray shale with claystone concretions and thin sandstone	100
	Beds covered with soil, probably soft sands and sandy shale	220
	Gray sandstone	5
	Gray sandy shale with brown and maroon disc-shaped concretions and thin platy sandstone	95
	Poorly bedded massive gray and red-brown sandstone	26
	Gray shale containing cream and maroon concretions	32
	Brown sandstone	20
	Sandy shale	10
	Red-brown sandstone	110
	Alternating beds of sandy shale and sandstone	60

Miles		*Thickness Feet*
	Soft gray sandstone with brown and yellow fossiliferous concretions	20
	Soft sandstone and sandy shale	110
20.5	Fossiliferous shale (base of Cook Mountain)	7
Total thickness of Cook Mountain exposed in this section		1,490
. . . .	. . . .	. . .
20.5	Soft sandy shale (Weches)	50
	Light gray shale	50
	Beds covered with sandy soil	353
	Shale and sandstone	50
	Reworked red clay with outcrops of pink and gray shale	170
	Soft gray sandstone	3
	Pink and gray sandy shale with calcareous concretions	60
	Thin-bedded sandstone with shale breaks, much iron detritus with sandstone and some calcareous concretions in shale	60
	Gray sandstone with hard brown sandstone inclusions at top	80
	Light gray shale	95
	Gray sandstone and shale	150
	Yellow-to-red-brown sandstone and thin shale beds	130
	Red shale	18
	Well bedded gray-brown and yellow sandstone	110
	Gray sandstone and shale, iron detritus with sandstone and calcareous concretions in shale	102
	Pink and gray shale	2
	Beds covered with reworked sandy soil	146
	Alternating shale and sandstone; sandstone has appearance of being banded with red, brown, and gray color	112
21.1	Gray sandstone with thin beds of brown sandstone (Palafox)	184
	Massive gray sandstone	20
	Soft gray sandstone with beds of hard brown flaggy sandstone	96
	Thin-bedded laminated gray and brown sandstone, *Venericardia* and lemon-yellow concretions in upper part	100
	Beds covered with soil	188
	Soft gray sandstone	166
	Beds covered with soil	203
	Thin-bedded reddish brown sandstone	99
	Soft gray sandstone	6
	Beds covered with reworked sandy clay	464
	Light gray shale with lemon-yellow concretions	1
	Beds covered with sandy soil	45
22.7	Dark gray shale (base of Mount Selman)	3
Total thickness of Mount Selman exposed in this section		3,316
. . . .	. . . .	. . .
22.7	Red-brown ripple-marked micaceous sandstone (top of Carrizo)	45
	Gray shale with lemon-yellow and bright red concretions	20
	Thin-bedded light gray platy sandstone	35
	Light green sandstone	4
	Yellow shale with much iron detritus	8
22.9	Massive white and red banded micaceous sandstone ("Once Lomas" sandstone)	135
	Thin-bedded and massive red sandstone with thin shale breaks	512
23.5	Red, brown, and gray sandstone (Arroyo San Domingo)	50
Total thickness of Carrizo exposed in this section		809
. . . .	. . . .	. . .
23.5	Dark gray clay shales with calcareous concretions (top of Indio)	500
24.0	Soft coarse-grained brown ripple-marked sandstones with hard dark brown calcareous concretions containing *Venericardia*, *Natica*, and oyster fragments and interbedded clays with hard red crystalline platy sandstone at base	300

Miles		*Thickness Feet*
24.5	Dark gray clay shales with yellow and brown calcareous concretions and thin platy brownish and greenish gray argillaceous sandstones..	90
24.7	Soft gray sandstone with numerous brownish gray calcareous concretionary masses some of which are fossiliferous..................	47
25.6	Gray clay shales with thin bands of orange-colored claystone and numerous bright yellow-to-gray calcareous concretions with cone-in-cone structure. Plentiful deep red disc-shaped ironstone concretions and a few beds of thin platy greenish-to-brownish gray argillaceous sandstone containing plant stem molds and ripple-marks....	83
	Soft light gray sandstone with bright yellow-to-brown concretionary masses at top..	30
	Gray-yellow-weathering arenaceous clay shales containing numerous yellow and brown calcareous concretions, deep red disc-shaped ironstone concretions, septarian concretions of log-like dimensions and others biscuit-shaped and 3 feet in diameter. Many concretions show cone-in-cone structure, and whole shale series is broken by a few thin beds of greenish-to-brownish gray platy argillaceous sandstone and yellow-brown calcareous sandstone. Bright yellow-to-orange claystone bands and gypsum are characteristic of most of the clay shale..	320
	Soft gray sugary sandstone containing large yellow-brown calcareous concretionary masses well exposed on La Palma ridge where Aldamas well of Ohio-Mexico Oil Corporation was drilled..........	30
	Dark gray shale and lenses of fine-grained sandstone with some siderite, pyrite, mica, and glauconite. Contains numerous reworked Midway and Cretaceous *Foraminifera*. Exposed in Rio Agualeguas between Paso de Coyote and San Javier..........................	1,840
Total thickness of Indio in this section...............................		3,240
. . . .		
	Dark gray calcareous shale containing Midway *Foraminifera* (section is from Ohio-Mexico Aldamas well and is not exposed along road where it can be measured)................................	660
38.6	Plaza at Gral. Trevino	

6. *Composite Fayette section, Rancherias-San Pedro de Roma.*—In the absence of Fayette beds in any of the cross sections given with this paper, a special Jackson section is presented to complete the stratigraphic column of the Eocene. This section is predicated on measured sections along the Rio Grande on both sides of the river between Roma and Rio Grande City, Texas, and takes into account the results found in the drilling of the Rancherias well of the Ohio-Mexico Oil Corporation, S.A.

It should be noted that the lenticular nature of the sandstones, particularly in the lower part of the Fayette section, makes the thicknesses of component parts of the formation variable over relatively short distances. For this reason it is exceedingly difficult to get satisfactory correlations of well logs with surface sections measured in the area. As noted, it is possible that there may be younger Jackson beds east of the Rio San Juan than the highest sandstones described in this sequence, but the following is believed to give a fairly typical section of the beds representing such Jackson deposition as is found within the limits of this sector.

Description	*Thickness Feet*
Villa Nueva sandstone member (uppermost beds of Fayette formation which admit of measurement). Coarse-grained soft gray sandstone commonly weathering brown with a fossiliferous horizon containing species of *Turritella*, *Volutocorbis*, and other fossils at its base	63
Yellow-weathering gray clay with much gypsum and volcanic ash	217
Sanchez sandstone member—ridge-forming soft gray sandstone with hard dark brown calcareous concretionary masses. Two very prolific fossil horizons containing variety of gastropods and bivalves are found in this sandstone series and several beds of sandstone with plentiful *Ostrea georgiana* are found at its base	139
Gray-yellow-weathering clay shales, red clays, oyster beds, and thin beds of soft gray platy sandstone. Lenticular sandstones of medium-to-coarse texture and ordinarily light colored. Volcanic ash locally associated with sandstones and much fossil wood, gypsum, and iron detrital material throughout whole shale section	370
Soft gray and yellow sandstone series with some hard brown nodular sandstone inclusions, some fossiliferous	50
Gray somber clay shale and pink-and-yellow-weathering sandy shale with a few oyster beds, fossil wood, and iron detritus	33
Roma sandstone member. Soft, coarse-to-medium-grained light gray sandstone with several horizons containing hard dark brown calcareous concretionary masses and others containing yellowish brown hard nodular sandstone masses in very soft sandy matrix. Several gravelly and conglomeratic beds near its base. A few oysters found throughout the whole sandstone and a good fossiliferous bed of small bivalves at its base	362
Gray somber clays with thin soft platy sandstones and numerous thick beds of oysters	135
Los Guerras sandstone member at base of Fayette formation. Soft gray sandstone with chalcedony-replaced gastropods and thick bed of oysters at top. Large biscuit-shaped harder sandstone masses in softer sandy matrix in upper part and lower part shows thin indurated hard brown layers as lenses in soft gray sandstone making outcrop of banded appearance. *Venericardia* in some bedding planes near base (Salineno sandstone of United States	48
Total thickness of Fayette beds in this section	1,417

For convenience in correlating with the Texas section of the lower Jackson, several forminiferal zones recognized on the American side of the river are indicated as they were found in the Rancherias well No. 1 of the Ohio-Mexico Oil Corporation.

Foraminiferal Zones	*Depth Feet*
First *Textularia dibollensis*	600
First *Operculina* sp.	670
First *Nonionella cockfieldensis*	890
First *Cibicides* sp.	1,000
First *Eponides yeguaensis*	1,030

TABLE I

SUMMARY OF THICKNESS OF EOCENE FORMATIONS IN NORTHEASTERN MEXICO

(Thickness in Feet)

Age	*Formations*		*Rio Grande River Composite*	*Laguna de Leche*	*Laredo-Monterrey Railroad*	*Laredo-Monterrey Highway*	*San Ignacio-El Sauz*	*Roma-Mier-Gral. Trevino*	*Rancherias-San Pedro Roma*
Jackson	Fayette		530 Average (*T*) 1600 (*L*)	—	—	—	—	—	1,417+
Claiborne	Yegua		493 Average (*T*) 668 (*L*)	—	—	—	—	1,543	—
	Cook Mountain		685 Average (*T*) 675 (*L*)	—	—	—	1,350	1,490	—
	Mount Selman	Upper Mount Selman	618 Average (*T*) 1,165 (*L*)	1,165 (*L*)	1,124	1,124	2,587	3,316	—
		Bigford member	340–700 (*T*) 670 (*L*)	759 (*N*)	804	804			
	Carrizo		118 (*T*) 125–250 (*L*)	1,122 (*N*)	1,179	1,176	947	810	—
Wilcox	Indio		600–800 (*G*) 815–877 (*T*) 1,188 (*N*)	1,518 (*N*)	1,919	1,985	2,930	3,240 (*W*)	—
	Midway		216 Average (*T*) 150–375 (*G*)	400	513 (*W*)	643	650 (?)	660 (*W*)	—

Note.—(*T*) Trowbridge, (*L*) Lonsdale, (*G*) Getzendaner, (*N*) Nielson, (*W*) Contact fron micropaleontologic examination of well samples, (?) Estimated.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), P. 1389

GEOLOGICAL NOTES

NEW HARDIN FIELD, LIBERTY COUNTY, TEXAS

Near Hardin, or 8 miles north of Liberty, the county seat of Liberty County, Texas, in the latter part of July, Jack Frazier *et al.* completed Lynott and Buffon No. 2, making 279 barrels of oil for the first 24 hours on a $\frac{1}{4}$-inch choke from a total depth of 7,690 feet. The producing horizon consists of a sand series in the upper Saline Bayou member of the Yegua formation of the Claiborne series, approximately between 450 feet and 500 feet below the top of the Cockfield.

The Gulf Producing Company was attracted to the area because of favorable pendulum results, and others became interested on account of favorable torsion-balance data. Reflection-seismograph work, however, was indefinite. Wells drilled in this general area previously indicated from the subsurface that a structure existed here. The first well, drilled by Frazier, $1\frac{1}{2}$ miles west of the discovery well, was abandoned as a dry hole, although it was approximately 100 feet higher than the discovery well and it had not reached the horizon producing in that well. O. L. Brace was the geologist who located the discovery well for Frazier and his associates and directed them to the abnormal area.

L. P. TEAS

HOUSTON, TEXAS
August, 1935

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), P. 1390

DISCUSSION

THOROLD SANDSTONE

In the May number of the *Bulletin* of The American Association of Petroleum Geologists (Vol. 19, No. 5, p. 702) appeared a note by Professor George H. Chadwick to the effect that the Thorold sandstone at Rochester is not of Thorold age and should be designated as the "Kodak." The following consideration of Professor Chadwick's views indicates that the addition of another term to the already overburdened nomenclature of the region may be unnecessary.

The presence of *Arthrophycus* in the Thorold of the Niagara Gorge and its absence in the "3 feet of 'white' sandstone" topping the red Medina in the Genesee Gorge are noted by Professor Chadwick. *Arthrophycus* does occur at this horizon in the Genesee Gorge. It is probably not plentiful in either locality, as during a number of days spent in the Niagara Gorge I did not see any in the Thorold there. This worm burrow is hardly significant in detailed correlation.

At Medina and at Glen Edyth, Professor Charwick found both his "Kodak" and the true Thorold with an intervening green shale. This green shale he states is not present at Rochester, which is an intermediate locality. The sections of Medina and Glen Edyth seem best explained on the basis of facial change. The shale at Medina appears to be basal Thorold and the beds beneath it upper Medina. At Glen Edyth the presence of a green shale is not the only peculiar thing about the section. It does not seem practical to correlate exactly two shale lenses which occur as far apart as Medina and Glen Edyth, considering the absence of shale at this horizon at intervening points and the differences in the two sections. Paucity of fossils makes this correlation especially hazardous.

Professor Chadwick quotes his paper of 1918[1] as indicating that the Thorold at Rochester is not closely related to the underlying Medina. This is a matter of opinion and it is the writer's that the conditions responsible for the origin of these formations make a logical sequence.

It therefore seems unnecessary to introduce a new term, first, because of the presence of *Arthrophycus* in the "gray band" at Rochester, although the index value of this fossil is open to question. In the second place, there is no consensus of opinion regarding the relationships existing between the "gray band" and the underlying red beds at the Genesee Gorge, and lastly, the irregularities in the section at various localities seem best explained on the basis of facial change, especially in the absence of paleontological evidence to the contrary. The Thorold probably becomes progressively younger eastward, but that is not sufficient reason for the introduction of a new term.

JOHN T. SANFORD

UNIVERSITY OF ROCHESTER
ROCHESTER, NEW YORK
July 22, 1935

[1] G. H. Chadwick, *Bull. Geol. Soc. America*, Vol. 29 (1918), pp. 327–68, footnote 334.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), PP. 1391-1394

REVIEWS AND NEW PUBLICATIONS

RECENT PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates. A list of technical periodicals available for loan to members and associates was published in the *Bulletin*, Vol. 18, No. 9 (September, 1934), pp. 1215–17.

AUSTRALIA

"Oil Possibilities in the West Kimberleys of Australia," by A. Wade. *Petrol. Times* (London), 33 (1935), p. 588.

CALIFORNIA

* "Tectonics of the Mount Diablo and Coalinga Areas, Middle Coast Ranges of California," by Bruce L. Clark. *Bull. Geol. Soc. America* (Washington, D. C.), Vol. 46, No. 7 (July 31, 1935), pp. 1025–78; 2 pls., 9 figs.

* "Geology of Mount Diablo and Vicinity," by Joseph A. Taff. *Bull. Geol. Soc. America*, Vol. 46, No. 7 (July 31, 1935), pp. 1079–1100; 1 pl., 1 fig.

COLOMBIA

* "Tertiary Fresh-Water Mollusks of the Magdalena Embayment, Colombia," by Henry A. Pilsbry and Axel A. Olsson, "With Tertiary Stratigraphy of the Middle Magdalena Valley," by O. C. Wheeler. *Proc. Acad. Nat. Sci. Philadelphia*, Vol. 87 (April 23, 1935), pp. 7–39; 1 index map, 1 table, 5 pls. of fossils.

GENERAL

* Fossil Non-Marine Mollusca of North America," by Junius Henderson. *Geol. Soc. America Spec. Paper No. 3* (1935). "Systematic List of Species," pp. 7–21; "Formation and Locality Lists of Species," pp. 22–50; "Systematic Annotated Catalogue," pp. 51–268; "Bibliography," pp. 269–90; "Index," pp. 291–313. Paper. 6.375×9.625 inches.

* "The Geological Surveys and Societies of the World," by R. S. G. Stokes. *Proc. Geol. Soc. South Africa*, pp. xxiii-lxii, to accompany *Trans.*, Vol. 38 (1935).

* "Reports on the Progress of Naphthology, 1934." Contains among others: "Geology of Petroleum," by V. C. Illing; "Geology of the Oilfields," by S. E. Coomber; "Geophysics," by H. Shaw; "Drilling," by M. C. Seamark; "The Scientific Control, Development and Production of Reservoirs," by C. J. May; "Production Technique," by A. C. Hartley; "Petroleum Literature," by Winifred S. E. Clarke; and "Statistics," by George Sell. *Jour. Inst. Petrol. Tech.* (London), Vol. 21, No. 140 (June, 1935), pp. 435–578.

* *Petroleum. Twenty-Five Years Retrospect.* A comprehensive and authoritative review of advances in petroleum technology during the years 1919–1935. By many authors. Includes chapters on "Petroleum Geology," by T. Dewhurst, and "Geophysics," by A. O. Rankine. *Inst. Petrol. Tech.* (Aldine House,

Bedford Street, Strand, London, W. C. 2, 1935). xix+219 pp., 47 illus. Cloth. Price, postpaid, $2.00.

* "Heutige Meeresablagerungen als Grundlagen der Beurteilung der Ölmuttergesteins-Frage" (Present Marine Deposition as the Basis for Review of the Problem of Petroleum Source Rock), by Karl Krejci. *Kli. Verwandte Salze und Erdöl* (Wilhelm Knapp, Halle, Saale, Mühlweg 19, Germany), Vol. 29, No. 14 (July 15, 1935), pp. 147–48. First of a continued article.

* "Problems on the Geology of Helium," by V. V. Belousov. *Trans. Bur. Natural Gas* (Moscow), No. 6 (1934). 74 pp., illus., including map of central Mid-Continent of United States. Pp. 72–73, summary in English.

Petroleum. The Story of an American Industry (1935). Second, larger edition of *Oil*, published by the American Petroleum Institute in 1930. Tells an understandable story of the industry's services and operations, and its economic contributions to society. Of importance to everyone interested in the petroleum industry. 96 pp. 6×9 inches. American Petroleum Institute, Room 2040, 50 West 50th Street, New York. Price, $0.15. Lower prices for quantity orders.

* "Thin-Section Mechanical Analysis of Indurated Sediments," by W. C. Krumbein. *Jour. Geol.* (Chicago), Vol. 43, No. 5 (July–August, 1935), pp. 482–96; 7 figs.

GERMANY

The Prussian Geological Survey, Berlin N 4, Invalidenstrasse 44, has recently published as its latest Bulletins, under date of 1933, the following:

* "Stratigraphische und lithogenetische Untersuchungen in Gebieten der Blätter Pferdsfeld und Sobernheim im Nahebergland (Beiträge zur Lithogenesis des Rotliegenden)" (Stratigraphic and Lithogenetic Research in the Area of the Pferdsfeld and Sobernheim Maps; Red-Bed Lithology), by Herman Reinheimer. New Ser., *No. 149.* 56 pp., geologic map and section.

* "Das Cenoman und die Plenus-Zone der sudetischen Kreide" (The Cenomanian and the Plenus-Zone of the Sudetic Cretaceous. Saxony, Schleswig, Bohemia), by Walter Häntschel. New Ser., *No. 150.* 161 pp., 1 map, 4 photographs, 1 pl. (26 figs. of fossils).

* "Das Devon im Gebiet der oberen Lenne" (The Devonian in the Region of the Upper Lenne. Sauerland), by Johannes Wolburg. New Ser., *No. 151.* 77 pp., 10 figs., 1 colored geologic map and 4 sections, 2 pls. of fossils.

* "Revision der Seeigel aus dem Norddeutschen Jura. I. Teil: Die irregulären Seeigel" (Revision of the Sea Urchins from the North German Jurassic. Part I: The Irregular Sea Urchins), by Karl Beurlen. New Ser., *No. 152.* 98 pp., 16 figs.

* "Über Mittelkreide und Tertiär in der Tiefbohrung Sieletz nebst Beschreibung der mittelkretazischen Fauna" (Middle Cretaceous and Tertiary in the Sieletz Deep Bore Hole. Province of Posen), by N. Polutoff. New Ser., *No. 155.* 80 pp., 5 figs.

* "Der unterkarbonische Vulkanismus in variskischen Gebirge Mitteldeutschland" (Lower Carboniferous Vulcanism in the Variscan Mountains of Middle Germany), by Kurt Gundlach. New Ser., *No. 157.* 59 pp., 2 figs., 4 photographs, 1 geologic map.

* "Spongienreste aus dem (oberturonen) Grünsand vom Kassenberg in Mülheim-Broich an der Ruhr" (Fossil Sponges from the Upper Turonian

Greensand of Kassenberg in Mülheim-Broich on the Ruhr), by Hermann Rauff. New Ser., *No. 158.* 74 pp., 20 figs., 5 pls. of fossils.

GREAT BRITAIN

"Prospects for Oil in Great Britain," by V. C. Illing. *Petrol. Times* (London), 33 (1935), pp. 655–57.

ILLINOIS

* "Oil and Gas Development in Illinois in 1934," by Alfred H. Bell. *Illinois State Geol. Survey Illinois Petroleum No. 26* (Urbana, July 20, 1935). 15 pp.

KANSAS

* "Contour Map of the Base of the Cherokee Shale in the Zinc-Lead District of Southeastern Kansas," by W. G. Pierce. *U. S. Geol. Survey Press Notice 103188* (July 19, 1935). 4 mimeographed sheets and 1 map.

MANCHURIA

"On the Sinian Stratigraphy of the Kuan Tung Province, South Manchuria," by Susumu Matsushita. *Ryojun Coll. Engin. Mem.*, Part I, Inouye Commem. Vol. (1934), pp. 339–51; Part II, Vol. 8, No. 2 (1935), pp. 31–45; 2 pls., 4 figs. More than 26,000 feet of almost unmetamorphosed and undeformed late Proterozoic geosynclinal deposits, previously regarded as continental in origin, here described as a great calcareous marine series in a typical geosyncline.

MOROCCO

* "Les recherches de petrole an Maroc," by M. Migaux. *Annal. Combus. Liquides* (Paris), No. 3 (May–June, 1935), pp. 403–36; 4 maps, 4 geologic sections; bibliography.

NORTH DAKOTA

* "Geology and Coal Resources of the Minot Area, North-Central North Dakota," by David A. Andrews, assisted by R. B. Simpson, F. R. Waldron, and L. E. Holmgren. *U. S. Geol. Survey Press Notice 103189* (August 5, 1935). 7 mimeog. pp., 1 folded map.

OKLAHOMA

"Maps of Coal Districts in Southeastern Oklahoma," by T. A. Hendricks, W. T. Thom, Jr., and M. M. Knechtel. *U. S. Geol. Survey* (1935). Five preliminary sheets in advance of publication of reports describing the geology of the coal-bearing areas: Lehigh district, Coal and Atoka counties; McAlester district, Pittsburg and Latimer counties; Wilburton district, Latimer County; Howe district, Le Flore, Haskell, and Latimer counties; and Stigler-Poteau district, Pittsburg, Haskell, and Le Flore counties. Available from the director of the U. S. Geol. Survey, Washington, D. C., or from W. W. Fleming, U. S. Geol. Survey, Mine Rescue Bldg., McAlester, Oklahoma. Price, $1.00 per copy, or $4.00 per set.

POLAND

* *Bull. Geol. Survey Poland*, Vol. 8, No. 1 (Warsaw, 1934). 199 pp., 10 pls., 9 figs. Contains: "Sub-Tortonian Surface of the Cretaceous in the Environs of Lwow," by H. Teisseyre, pp. 29–35 in Polish, pp. 35–38 résumé in

French, 1 map; "Cretaceous Rocks Between the Towns of Pilica and Szczekociny," by Z. Sujkowski, pp. 39–70 in Polish, pp. 70–74 résumé in French, 4 figs., 5 pls. (1 map and 10 photomicrographs); "Remarks on the Structure of the Carpathian Flysch," by H. Swidzinski, pp. 75–141 in Polish, pp. 141–99 résumé in French, 4 figs., 4 pls. (2 maps, 2 photographs).

TENNESSEE

* "The Pre-Chattanooga Development of the Nashville Dome," by Charles W. Wilson, Jr. *Jour. Geol.* (Chicago), Vol. 43, No. 5 (July–August, 1935), pp. 449–81; 9 figs.

TEXAS

* "Progress of the West Texas Search for Ordovician Production Shows Possibilities," by George A. Kroenlein. *Oil Weekly* (July 22, 1935), pp. 31–34; subsurface structure map (Ellenburger).

WYOMING

* "Bureau of Mines Analyzes Oil from New Wyoming Well" (Big Medicine Bow field, Carbon County). *U. S. Bur. Mines Press Release 3081* (July 12, 1935). 2 mimeographed sheets.

Native market at Amecameca with Mount Ixtaccihuatl in background.
Cut by courtesy of Missouri Pacific Lines.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), PP. 1395-1401

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of the nominees, he should send it promptly to J. P. D. Hull, business manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

John Burchard Bush, New Orleans, La.
Robert M. Whiteside, Fanny Carter Edson, L. L. Foley
Charles Reiter Canfield, Los Angeles, Calif.
Stanley G. Wissler, Harold W. Hoots, Earl B. Noble
Frank Buckley Conselman, Hobbs, N. M.
E. B. Branson, H. S. McQueen, W. B. Wilson
Parke A. Dickey, Oxford, Pa.
Oliver B. Hopkins, O. C. Wheeler, W. W. Waring
Leland Willard Jones, Edmond, Okla.
Clyde M. Becker, Frank R. Clark, Jess Vernon
Paul Holland Price, Morgantown, W. Va.
R. C. Tucker, David B. Reger, Ray V. Hennen

FOR ASSOCIATE MEMBERSHIP

George Odwin Cate, Houston, Tex.
Dave P. Carlton, J. E. LaRue, Glenn E. Bader
Robert C. Dunlap, Jr., Dallas, Tex.
Eugene McDermott, J. C. Karcher, Roland F. Beers
Julius Benjamin Garrett, Jr., Houston, Tex.
Henry V. Howe, Merle C. Israelsky, Karl E. Young
Sam Kornfeld, Tulsa, Okla.
Lawrence J. Zoller, W. E. Bernard, Kent K. Kimball
Mark Eugene Stump, Tulsa, Okla.
G. C. Potter, H. E. Lillibridge, W. Z. Miller

FOR TRANSFER TO ACTIVE MEMBERSHIP

Floyd Melvin Ayers, Midland, Tex.
H. B. Fuqua, B. E. Thompson, J. B. Lovejoy
James P. Fox, Mexico, D. F.
G. C. Gester, Stephen H. Gester, George M. Cunningham
Mark Cyril Malamphy, Rio de Janeiro, Brazil
D. C. Barton, R. L. Paxon, P. B. Leavenworth

SUPPLEMENTARY MEMBERSHIP LIST, SEPTEMBER 1, 1935

Members	76
‖Associates	56
*Honorary	1
Total additions since publication of list in March *Bulletin*	133

‖Absher, K. B., 1608 W. Pine Ave., Wichita, Kan.
‖Adams, Elmo W., Bin H, Taft, Calif.
‖Allen, Stanley R., 215-B Humble Bldg., Houston, Tex.
Anderson, G. E., Dept. of Geology, University of Oklahoma, Norman, Okla.
‖Ayers, Floyd M., Gulf Prod. Co., Midland, Tex.
Barnes, Chester F., Box 306, Big Spring, Tex.
Bartosh, E. J., Bankline Oil Co., 634 S. Spring St., Los Angeles, Calif.
‖Beck, A. F., Carter Oil Co., Box 801, Tulsa, Okla.
Bendrat, T. A., 91 S. Kanawha St., Beckly, W. Va.
Benton, L. B., 1730 Sixth Ave., Fort Worth, Tex.
‖Berry, Harry L., 2503 W. Park Pl., Oklahoma City, Okla.
Bickel, C. Russell, Shell Petr. Corp., Box 417, McPherson, Kan.
‖Bird, Helen Pier, Humble Oil & Refg. Co., McCamey, Tex.
Blanchard, W. Grant, Jr., 812 Dallas Bank & Trust Bldg., Dallas, Tex.
‖Boehms, Eugene F., 214 S. Madison St., San Angelo, Tex.
‖Boots, Paul H., Apartado 35, Ciudad Bolivar, Venezuela, S. A.
Boyle, A. C., Jr., Jensen, Utah
‖Breedlove, Robert Leeroy, Box 774, Smithville, Tex.
Brossard, Eugene E., Apartado 35, Ciudad Bolivar, Venezuela, S. A.
Bryan, Frank, 3420 Chateau Ave., Waco, Tex.
Buck, Loren I., 216 N. Oak, Pratt, Kan.
Burtt, John G., Shell Oil Co., 508 Shell Bldg., Los Angeles, Calif.
‖Cartwright, Weldon E., Humble Oil & Refg. Co., Anahuac, Tex.
Conkling, Russell C., Box 475, Midland, Tex.
‖Conley, J. N., 1321 S. Rockford, Tulsa, Okla.
‖Cronin, K. Stewart, Pure Oil Co., Box 271, Tulsa, Okla.
‖Curran, Bernard E., Apartado 234, Maracaibo, Venezuela, S. A.
Dane, Carle H., U. S. Geological Survey, Washington, D. C.
Denman, C. E., 1523 Stone St., Great Bend, Kan.
‖Dillard, W. Reese, Box 2040, Tulsa, Okla.
Egan, J. A., University Club, Tulsa, Okla.
‖Elliott, Andrew C., Box 111, Houston, Tex.
Elson, William H., 422 Beacon Life Bldg., Tulsa, Okla.
Ely, Fred B., 120 Wall St., New York, N. Y.
Fabiani, Ramiro, Instituto Geologo-R., Universita, via Maqueda, Palermo 7, Italy
‖Ferguson, Glenn C., Box F., Compton, Calif.
‖Ferguson, W. B., Box 691, Brenham, Tex.
Frischknecht, Gustav, Point-a-Pierre, Trinidad, B. W. I.
‖Fritz, William Clayton, Midland, Tex.
Garnjost, F. W., Spuyten Duyvil, New York, N. Y.
‖Gile, Richard E., Box 298, Midland, Tex.
‖Gill, J. Willard, 707 N. Sixteenth St., Waco, Tex.
Gregersen, Albert, 929 S. Broadway, Los Angeles, Calif.
Hall, Ellis A., Box 211, Abilene, Tex.
Hansell, James M., 1030 Milam Bldg., San Antonio, Tex.
*Harris, Gilbert D., Dept. of Geology, Cornell University, Ithaca, N. Y.
Harris, S. F., Broken Arrow, Okla.
‖Harriss, Trewitt F., Hotel Maywood, Corning, Calif.
Hendricks, Thomas A., U. S. Geological Survey, Washington, D. C.
Henquet, Roger, 517 Jergins Trust Bldg., Long Beach, Calif.
Henry, W. W., 1015 Kennedy Bldg., Tulsa, Okla.
‖Heston, J. Ed., c/o H. L. Doherty Co., 60 Wall St., New York, N. Y.
Hoard, J. O., 623 Esperson Bldg., Houston, Tex.
‖Hobson, H. D., Continental Oil Co., 700 Edison Bldg., Los Angeles, Calif.
Horkey, William E., 503 Kennedy Bldg., Tulsa, Okla.
‖Howard, Dan O., 309 N. E. Thirteenth St., Oklahoma City, Okla.

||Hubman, Ralph G., Lago Petr. Corp., Apartado 172, Maracaibo, Venezuela, S. A.
Hughes, C. Don, 1901 Van Buren St., Amarillo, Tex.
||Jones, Charles T., 412 W. Adams St., McAlester, Okla.
||Kaye, M. Kamen, Caracas Petr. Corp., Apartado 89, Caracas, Venezuela, S. A.
Kelley, H. Allen, 1944 Milan Ave., S. Pasadena, Calif.
Kelly, Donald, Box 600, Wichita Falls, Tex.
||Kelsey, Lewis O., 1802 Alamo Natl. Bldg., San Antonio, Tex.
Kerlin, M. L., Jr., Box 494, Hamlin, Tex.
Keyes, Wilson, Box 872, Midland, Tex.
Knechtel, M. M., U. S. Geological Survey, Washington, D. C.
Knipe, R. E., 106 W. Main, Marshall, Ill.
Kotick, Ottmar F., 2802 Nineteenth St., Bakersfield, Calif.
||Langton, Claude M., 1020 Salinas Ave., Laredo, Tex.
Leach, Thomas W., 1611 Natl. Bank of Tulsa Bldg., Tulsa, Okla.
Leonard, Clarence Z., Box 536, Athens, Tex.
||Lock, James, Box 1291, Jacksonville, Tex.
||Lockett, George L., Apartado 35, Ciudad Bolivar, Venezuela, S. A.
Mason, Charles C., Standard Oil Co. of Venezuela, Caripito, Venezuela, S.A.
||Mayer, Edward A., Box 86, Fairview, Okla.
||McHugh, W. E., 610 Ellis Singleton Bldg., Wichita, Kan.
Michelin, James, 707 Edwards-Wiley Bldg., Los Angeles, Calif.
Miller, Charles P., Drawer I, Hobbs, N. Mex.
||Miller, W. Keith, Box 261, Lamar, Colo.
||Moser, C. E., R. D. 2, Box 11-M, Ventura, Calif.
Nance, A. G., Box 2038, Pittsburgh, Pa.
||Neer, Carl J., Humble Oil & Refg. Co., Houston, Tex.
||Newton, William W., 1311 Republic Bank Bldg., Dallas, Tex.
||Ohrenschall, Robert D., 518 N. Bluff St., Wichita, Kan.
||Perryman, James D., Box 273, Golden, Colo.
Pike, William S., Jr., Box 494, Hamlin, Tex.
Preece, Rae, 833 Milam Bldg., San Antonio, Tex.
Purzer, Joseph, Geological Dept., Phillips Petr. Co., Bartlesville, Okla.
Ray, W. C., 224 W. Beauregard, San Angelo, Tex.
Reid, Robert P., Foster Petr. Co., Bartlesville, Okla.
Riggs, George D., Box 1538, Pampa, Tex.
Rivero, Manuel, Caribbean Petr. Co., Maracaibo, Venezuela, S. A.
||Roberts, Thomas N., 1205 N. W. Thirty-Fourth St., Oklahoma City, Okla.
Rowley, A. B., 1559 S. Yorktown, Tulsa, Okla.
||Russell, Hewlett A., Box 378, Merced, Calif.
||Sackman, Harold A., 701 E. Osage, McAlester, Okla.
||Sax, Henry, Adr. Pauwstr. 19, den Haag, Holland.
Scholl, Guy J., Panhandle Bldg., Wichita Falls, Tex.
||Scott, Edward W., Union Oil Co., 1119 Union Oil Bldg., Los Angeles, Calif.
Scott, Gerald Hugh, Apex (Trinidad) Oilfields, Ltd., P. O. Siparia, Trinidad, B. W. I.
Seager, O. A., Box 815, Wilson, Okla.
||Shelby, Thomas H., Jr., 215-B Humble Bldg., Houston, Tex.
Sherar, Stuart, Box 801, Tulsa, Okla.
||Simkins, J. J., 410 N. Haskell Ave., Dallas, Tex.
Snively, H. Norman, Box 445, Rawlins, Wyo.
||Stasney, H. R., Albany, Tex.
Stauffer, Hans K., U. B. O. T., Port Fortin, Trinidad, B. W. I.
Stewart, Charles H., Navarro Oil Co., Humble Bldg., Houston, Tex.
Stilley, Earl M., Staley Bldg., Wichita Falls, Tex.
Sutton, Chase E., Pure Oil Co., Box 239, Houston, Tex.
||Tapp, Theodore L., Apartado 234, Maracaibo, Venezuela, S. A.
||Thomas, William T., Box 1348, Fort Worth, Tex.
Thorne, B. L., Canadian Pacific Railway Co., Dept. of Nat. Resources, Calgary, Alta., Canada
Upson, M. E., Box 1290, Fort Worth, Tex.
||Van Beveren, O. F., Tioga Hotel, Merced, Calif.
Van der Schilden, B., Bataafsche Petr. Mij., 30 Carel Van Bylandtlaan, The Hague, Holland
A. van Weelden, c/o M. H. Kotzebue, 1526 S. Victor, Tulsa, Okla.

Vance, W. R., Box 2038, Pittsburgh, Pa.
||Wagoner, George E., Carter Oil Co., Box 801, Tulsa, Okla.
Walker, K. A., 325 W. Sixth Ave., Bristow, Okla.
Ward, Roderick C., Box 608, Lafayette, La.
||Warren, Howard C., 1907 Esperson Bldg., Houston, Tex.
Webster, Hugh B., Standard Oil Co. of Calif., 225 Bush St., San Francisco, Calif.
||Wesley, George R., Dept. of Mines & Minerals, Lexington, Ky.
||West, W. W., Baker, Mont.
White, Kirk S., 434 Kennedy Bldg., Tulsa, Okla.
Whortan, Raymond A., 705 Fourth Natl. Bank Bldg., Wichita, Kan.
Williams, F. S., W. C. McBride, Inc., McPherson, Kan.
Woolley, Glen C., Y.M.C.A., Wichita, Kan.
||Wright, Randall, Box G-2, Ventura, Calif.
Wynn, Warren H., Box 859, Shawnee, Okla.
Young, Wilber H., 103 W. Main St., Titusville, Pa.
Zavoico, B. B., 632 Mayo Bldg., Tulsa, Okla.

MID-YEAR MEETING OF THE ASSOCIATION AND ANNUAL MEETING, SAN ANTONIO GEOLOGICAL SOCIETY MEXICO CITY, OCTOBER 16, 17, 18, AND 19, 1935

GENERAL INFORMATION

Road condition.—The contractor who is building the road is certain that it will be open for all-weather traffic, a month before the meeting.

Weather conditions.—It is said, by those who live in Mexico City, that the last 2 weeks in October are the best part of the year.

Hotel accommodations.—The Regis Hotel will be headquarters for the convention. If you send in a request for a room and later find you can not come, please wire Joseph M. Dawson, 1105 Alamo National Building, San Antonio, so that your reservation may be used for someone else. It is important to make reservations immediately for your greater convenience.

HOTEL REGIS SPECIAL RATES FOR A.A.P.G. CONVENTION

(Approximate rate of exchange between U. S. currency and Mexican currency, $3.55 pesos for each American dollar)

	Amer. Cy.	*Mex. Cy.*
Single rooms (three-quarter bed)	$2.25	$ 8.00 1 person
	3.09	11.00 2 persons
Double rooms (2 three-quarter beds)	3.38	12.00 2 persons
	4.22	15.00 3 persons
Deluxe space, front double rooms (2 three-quarter beds)	5.63	20.00 2 persons
	6.47	23.00 3 persons
Suites, bed-room, parlor, and bath (2 double beds)	8.45	30.00 2 persons
	9.88	35.00 3 persons

All rooms are equipped with private bath.

The additional $3.00 pesos charge for extra persons provides for an extra bed in the double rooms.

Reservation requests should include the following information and be forwarded, preferably by air mail, to Joseph M. Dawson, 1105 Alamo National Building, San Antonio, Texas.

Name____________________

Address____________________

Number of people__________ Coming by car, rail, boat, or air__________

Type of room desired__________ Price__________

Date of arrival__________ Duration of visit__________

Airplane flight over "Popo"____________________

Government assistance.—The Mexican Government is providing the best in the way of buildings, immigration facilities, and English-speaking historians and scientists to make this meeting a success. A special attempt is being made to include many features which will be of special interest to the ladies. Because of places to be visited, technical sessions will be held only in the morning. Trips to points of interest will be conducted by English-speaking historians and geologists who will add interest to the experience that would be impossible to get with ordinary guides.

Geological Institute of Mexico.—The Geological Institute of Mexico, expressing the sentiments of the Government authorities and Mexican geologists has attempted to do everything possible to give the visiting American geologists a hearty welcome. It is hoped that their brief visit to this country may be a pleasant and profitable one, and an experience long to be remembered.

The Geological Institute of Mexico has formed a reception committee for this occasion composed of the following persons.

President: Sr. Ing. Manuel Santillan, Sub-Secretary of the National Economy and director of the Geologic Institute of Mexico

Vice-Presidents: Sr. Ing. José G. Aguilera, former director of the Geologic Institute of Mexico

Sr. Dr. Carlos Burkhardt, former paleontologist for the Geologic Institute of Mexico

Sr. Ing. Ezequiel Ordoñez, former geologist for the Geologic Institute of Mexico

Vocales: Ing. Juan B. Gilson, chief of the Petroleum Department of the Department of the National Economy

Ing. Teodoro Flores, geologist for the Geologic Institute of Mexico

Prof. Dr. F. K. G. Mülleried, geologist for the Geologic Institute of Mexico

Ing. Alfonso Barnetche, geologist for the Geologic Institute of Mexico

San Antonio Geological Society.—The committee of the San Antonio Geological Society headed by its president, Joseph M. Dawson, is composed of the following persons: William G. Kane, Saltillo, Mexico; Philip Schoeneck, Laredo, Texas; William Spice, San Antonio, Texas; Olin G. Bell, Laredo, Texas.

The committee for arrangements in Mexico City is composed of the following: Ing. Ezequiel Ordoñez, William G. Kane, Lowell J. Ridings.

TENTATIVE OUTLINE OF ACTIVITIES

WEDNESDAY, OCTOBER 16, MORNING

8:30 Registration at Hotel Regis

10:00 Sessions in Palace of Fine Arts, presided over by Sr. Ing. Manuel Santillan and United States Ambassador, Josephus Daniels

1. Address of welcome, by Hon. Sr. D. Cosme Hinojosa, Mayor of Mexico City, Federal District, interpreted by Ing. Ezequiel Ordoñez
2. General Geology of Mexico, by Ing. José G. Aguilera
3. Physiographic Provinces of Mexico, by Ing. Ezequiel Ordoñez

OCTOBER 16, AFTERNOON

2:30 Trip through Museum of Archaeology

3:30 Trip through Chapultepec Castle, including folk dances in this historic and beautiful setting

5:30 Reception of all geologists and wives at American Embassy by Hon. Mr. and Mrs. Josephus Daniels

OCTOBER 16, NIGHT

1. Symphonic Orchestra Concert at National Theater
2. Short talk giving historical setting for sights in and near Mexico City

This evening will be an exclusive gathering with Mexico City's social and diplomatic circles as our hosts, in one of the world's most beautiful theaters. The presentation of the concert is a compliment from the following scientific societies in Mexico City: Sociedad Mexicana de Geografía y Estadística; Academia Nacional de Ciencias A. Alzate; Asociación de Ingenieros y Arquitectos de México; Ateneo de Ciencias y Artes de México; and Instituto Geológico Nacional

THURSDAY, OCTOBER 17, MORNING

10:00 Technical session, presided over by Dr. Fernando Carranza, Rector of the National University of Mexico

1. Geology of Eocene and Northeastern Mexico, by William G. Kane
2. Paleogeography of Border Province of Mexico Adjacent to West Texas
3. Geology of Tampico Embayment, by Thomas Callahan; Tampico Oil Fields, by J. L. Tatum

OCTOBER 17, AFTERNOON

Conducted tour to recently excavated lava-covered convent at San Angel and to beautiful Desert of the Lions

OCTOBER 17, NIGHT

Dinner dance in Don Quixote Room of Regis Hotel, a la Mexicana

FRIDAY, OCTOBER 18, MORNING

Trip at 8:30 to Pyramids conducted by one of Mexico's leading historians. Luncheon in great cave, given by one of Mexico's foremost geologists and Government officials. Leisurely study of Pyramids Museum and stops at points of interest, on return to Capital

OCTOBER 18, AFTERNOON

1:00 Address by A. I. Levorsen, president of The Association, introduced by Joseph M. Dawson, president of the San Antonio Geological Society
1:30 Conducted tour of the Museum at the Pyramids
3:30 Visit to Acolman Monastery on return to Mexico City

OCTOBER 18, NIGHT

Jai-alai or Basque game of pelota at Frónton Mexico

SATURDAY, OCTOBER 19

9:00 Trip to cradle of American mining industry and one of most charming artist-haunts in America. Trip conducted and luncheon donated by Lowell J. Ridings, who will give 30-minute address on "Mining in Mexico". Return through Cuernavaca to Mexico City.

Tentative arrangements are being made for airplane flights over Popocatepetl, a snow-covered semi-active volcano that stands guardian 18,000 feet high over the Valley of Mexico; this trip will be made in a Pan-American Airways trimotor plane and will be the thrill of a life-time for any who want to take it. The cost will be from $10.00 to $15.00 (U.S.) per person, according to the number who make the trip.

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

A. IRVING LEVORSEN, *chairman*, Tulsa, Oklahoma
E. C. MONCRIEF, *secretary*, Wichita, Kansas
WILLIAM B. HEROY, New York, N. Y.
FRANK A. MORGAN, Los Angeles, California
L. C. SNIDER, New York, N. Y.

GENERAL BUSINESS COMMITTEE

SAM M. ARONSON (1930)
ARTHUR A. BAKER (1936)
R. F. BAKER (1937)
WILLIAM A. BAKER (1937)
ROY M. BARNES (1937)
R. A. BIRK (1936)
ROBERT L. CANNON (1937)
IRA H. CRAM (1937)
E. F. DAVIS (1936)
THORNTON DAVIS (1937)
FRANK W. DEWOLF (1937)
C. E. DOBBIN (1937)
H. B. FUQUA (1937)
L. W. HENRY (1937)
WILLIAM B. HEROY (1936)
JAMES W. KISLING, JR. (1937)
A. I. LEVORSEN (1937)
THEODORE A. LINK (1937)
GERALD C. MADDOX (1937)
E. C. MONCRIEF (1936)
JAMES G. MONTGOMERY, JR. (1937)
FRANK A. MORGAN (1936)
L. MURRAY NEUMANN (1936)
KENNETH DALE OWEN (1937)
G. W. SCHNEIDER (1937)
GAYLE SCOTT (1936)
E. F. SHEA (1937)
L. C. SNIDER (1936)
CLARE J. STAFFORD (1937)
J. D. THOMPSON, JR. (1936)
J. M. VETTER (1936)
LOUIS N. WATERFALL (1937)
MAYNARD P. WHITE (1936)
NEIL H. WILLS (1937)

RESEARCH COMMITTEE

DONALD C. BARTON (1936), *chairman*, Humble Oil and Refining Company, Houston, Texas
HAROLD W. HOOTS (1936), *vice-chairman*, Union Oil Company, Los Angeles, California
M. G. CHENEY (1937), *vice chairman*, Coleman, Texas

R. S. KNAPPEN (1936)
W. C. SPOONER (1936)
PARKER D. TRASK (1936)
ROBERT H. DOTT (1937)
K. C. HEALD (1937)
F. H. LAHEE (1937)
H. A. LEY (1937)
R. C. MOORE (1937)
F. B. PLUMMER (1937)
JOHN G. BARTRAM (1938)
C. E. DOBBIN (1938)
STANLEY C. HEROLD (1938)
THEODORE A. LINK (1938)
C. V. MILLIKAN (1938)
JOHN L. RICH (1938)
C. W. TOMLINSON (1938)

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL

FREDERIC H. LAHEE (1937)

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

IRA H. CRAM, *chairman*, Pure Oil Company, Tulsa, Oklahoma

JOHN G. BARTRAM
M. G. CHENEY
ALEXANDER DEUSSEN
B. F. HAKE
G. D. HANNA
M. C. ISRAELSKY
A. I. LEVORSEN
C. L. MOODY
R. C. MOORE
ED. W. OWEN
J. R. REEVES
ALLEN C. TESTER
W. A. THOMAS

TRUSTEES OF REVOLVING PUBLICATION FUND

CHARLES H. ROW (1936)
RALPH D. REED (1937)

TRUSTEES OF RESEARCH FUND

ROBERT H. DOTT (1936)
G. C. GESTER (1937)

FINANCE COMMITTEE

JOSEPH E. POGUE (1936)
E. DEGOLYER (1937)
THOMAS S. HARRISON (1938)

COMMITTEE ON APPLICATIONS OF GEOLOGY

FRANK RINKER CLARK, *chairman*, Box 931, Tulsa, Oklahoma

WILLIAM H. ATKINSON
ARTHUR E. BRAINERD
HAL P. BYBEE
HERSCHEL H. COOPER
CAREY CRONEIS
H. B. HILL
EARL P. HINDES
MARVIN LEE
S. E. SLIPPER
H. S. MCQUEEN
E. K. SOPER
J. M. VETTER

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 19, NO. 9 (SEPTEMBER, 1935), PP. 1402-1404

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

T. K. KNOX, formerly with the Saxet Gas Company, Houston, is now with the Republic Natural Gas Company, 803-4 Nixon Building, Corpus Christi, Texas.

ANDREW C. WRIGHT has changed his address from Bryan, Texas, to Box 1595, Shreveport, Louisiana.

S. ZIMERMAN, geologist with the Carter Oil Company, and located at Alma, Michigan, and Miss Bess Barkley, of Guthrie, Oklahoma, were married July 19 at Chicago, Illinois.

R. J. STEEL, geologist with the Indian Territory Illuminating Oil Company, has been transferred from Bartlesville, Oklahoma, to Midland, Texas.

ROBERT L. KIDD, geologist with the Empire Companies, has moved from Larned, Kansas, to Bartlesville, Oklahoma.

RALPH A. KOENIG, formerly of Carlsbad, New Mexico, is now with The Texas Company, Box FF, Hobbs, New Mexico.

R. S. CHRISTIE, geologist with the Amerada Petroleum Corporation, and formerly stationed at Longview, may now be addressed at the company's office in Fort Worth, Texas.

JOHN T. LONSDALE has resigned from the faculty at the Agricultural and Mechanical College of Texas to accept a position on the faculty of Iowa State College, Ames, Iowa.

GLENN GRIMES, chief geologist for Wirt Franklin Petroleum Corporation and Cromwell-Franklin Oil Company, discussed "Revision of the Permian-Pennsylvanian Contact on the North American Continent" before the regular luncheon meeting of the Oklahoma Geological Society, July 19.

H. F. SMILEY, consulting geologist and engineer, has transferred headquarters from Wichita Falls to Fort Worth, Texas, with offices on the 14th floor of the Fort Worth National Bank Building.

ROBERT M. FRANKS has changed his address from McAllen, Texas, to Box 186, Alice, Texas.

W. W. West, formerly at Wichita, Kansas, may now be addressed at Baker, Montana.

GEORGE A. KROENLEIN is located at Carlsbad, New Mexico. His address is Box 22.

GLENN D. ROBERTSON, geologist with the Shell Petroleum Corporation, has been transferred from Hobbs, New Mexico, to Houston, Texas.

RUSSELL C. CONKLING is a member of the firm of Green and Conkling, independent operators in West Texas. His address is Box 475, Midland, Texas.

DANA M. SECOR has been promoted to the position of district geologist of the Panhandle division of Skelly Oil Company after serving as assistant geologist of the company's Gulf Coast division. His address is Pampa, Texas.

C. L. MOHR, geologist with the Indian Territory Illuminating Oil Company, has been transferred from Midland, Texas, to Bartlesville, Oklahoma.

ALEX W. TIEDEMANN has been transferred from the St. Louis, Missouri, office of the Shell Petroleum Corporation, to the Tulsa, Oklahoma, office.

K. STEWART CRONIN, geologist with the Pure Oil Company, and formerly at Houston, Texas, is now located at Tulsa, Oklahoma.

CLARE CLARK, formerly with the United States Geological Survey in South Dakota, has accepted a position with the Indian Territory Illuminating Oil Company geological staff.

T. E. WEIRICH, geologist with the Phillips Petroleum Company, stationed at Nashville, Tennessee, for the past year and a half, has moved to 1304 Cherokee Street, Bartlesville, Oklahoma. His work has consisted of regional studies in the central interior of the United States, east of Mississippi River, and will now be continued west of the Mississippi.

R. A. RANK is geologist for the Navarro Oil Company at Houston, Texas. His mail address is 1924 Harold Street.

WALTER E. HOPPER has moved from Shreveport, Louisiana, to become adviser on oil and gas to the Securities and Exchange Commission at Washington, D. C.

STAN LESNIAK is in the geological department of the Phillips Petroleum Company, Seismic Party No. 1, Box 1177, Henryetta, Oklahoma.

M. T. HALBOUTY, recently with the Yount-Lee Oil Company, at Beaumont, has accepted the position as chief geologist and petroleum engineer for Glenn H. McCarthy, Inc., and is located at 1504 Sterling Building, Houston, Texas.

THEODORE A. LINK modestly suggests that some of the boys who thought his 86 in the Association golf tournament at Wichita last March was a fluke may be interested in the news that he recently made a hole in one at the Calgary Golf and Country Club, on the eighth hole which is 200 yards long. The next A.A.P.G. tournament will be held at the twenty-first annual meeting at Tulsa, Oklahoma, March 19–21, 1936.

CHARLES E. DECKER, professor of paleontology at the University of Oklahoma, is spending the summer at the State Museum in Albany, New York, studying the graptolites of several horizons in Oklahoma and Arkansas.

WALTER K. LINK, Standard Oil Company geologist in the Dutch East Indies for several years, has been transferred to the United States. His address is Geological Department, Carter Oil Company, Tusla, Oklahoma.

BERNARD SMITH has been appointed director of the British Geological Survey and Geological Museum, succeeding John Flett, retired.

JAMES H. HANCE, mining engineer and geologist of Salt Lake City, is now dean of the School of Mines, University of Alaska, College, Alaska.

C. P. PARSONS is a vice-president of the Halliburton Oil Well Cementing Company of Duncan, Oklahoma.

ROBERT B. NEWCOMBE, assistant State geologist of Michigan, has resigned to become vice-president of the Associated Petroleum Company of Detroit. He is succeeded on the Survey by Gerald E. Eddy.

JOHN CAMPBELL MERRIAM, president of the Carnegie Institution at Washington, and Raymond C. Moore, State geologist of Kansas, were the United States delegates to the centenary celebration of the Geological Survey of Great Britain, in London, July 3–5.

W. T. THOM, JR., associate professor of geology at Princeton University, has been appointed full professor.

B. D. STEWART, of the United States Geological Survey, has been appointed Commissioner of Mines for Alaska, under a recent act of the Territorial Legislature establishing a Department of Mines.

G. C. GESTER is chief geologist for Gold Gravel Products, Inc., Wallace, California.

CHARLES F. BASSETT, recently engaged in an underground water survey in the Michigan State forests, is now connected with the University of Kansas City. His address is 6121 Holmes Street, Kansas City, Missouri.

H. NORMAN SNIVELY, petroleum geologist, may be addressed at Box 445, Rawlins, Wyoming.

H. ALLEN KELLEY is geologist for the Bankline Oil Company at Los Angeles, California.

J. WHITNEY LEWIS may be addressed at Apartado 744, Santo Domingo, Dominican Republic.

GEORGE L. HARRINGTON has returned to the United States after several years in northern Argentina and southern Bolivia. His address is 1319 Bryant Street, Palo Alto, California.

NORMAN HARDY, who has been in the Dutch East Indies for the past 4 years for the Standard Oil Company of California, has now returned to California for his vacation. Before returning to California he made a tour of parts of Europe.

A number of the members of the Standard Oil Company of California staff who had been working in Arabia have returned to California for their vacations. They include BERT MILLER, THOMAS H. KOCH, and A. B. BROWN.

R. C. KERR, of the Continental Air Map Company, will return later, after he has visited various places in Europe.

COE S. MILLS, formerly at Shreveport, Louisiana, is now with the Marathon Oil Company at Jasper, Texas.

W. H. COURTIER is in the geophysical department of the Phillips Petroleum Company, Bartlesville, Oklahoma.

C. L. MOODY, of the Ohio Oil Company, Shreveport, Louisiana, talked on "Lower Cretaceous Oil and Gas in Louisiana," before the San Antonio Geological Society, following dinner at the San Antonio Petroleum Club, August 19. A new moving picture film, "The Mexico City Highway," was presented by W. H. FURLONG of the Pan-American Highways Commission.